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ELEMENTARY GENERAL PSYCHOLOGY

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ELEMENTARY GENERAL PSYCHOLOGY

By

SAMUEL W. FERNBERGER

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To Three Friends

E.B.T.

WHO FIRST AROUSED MY INTEREST IN PSYCHOLOGY

F.M.U.

WHO INITIATED ME INTO EXPERIMENTAL RESEARCH

E.W.F.

WHO HAS HELPED FOR MANY YEARS TO MAKE
PSYCHOLOGY A HAPPY VOCATION

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PREFACE

This book is the product of nearly thirty years of teaching elementary psychology to undergraduate students. It is not a text written for the eyes of psychologists. It is an attempt to give the immature beginning student a first orientation in the material of this science. The mastery of this text will not make the reader a "psychologist." But it should give the student a general background of psychological point of view and of psychological fact so that he can read or study more adequately, easily and correctly in any of the more advanced special fields of psychology. If this is true, the author will have been successful in everything he has hoped to accomplish. Furthermore the reader should have acquired an acquaintance with the special vocabulary of psychology. Like every other science, psychology has given special meaning to some words and has invented other words to describe special ideas. Without a knowledge of these special meanings, an intelligent reading of psychology is impossible.

Confession must be made that I am old fashioned psychologist. I still believe that a study of consciousness comprises a very important part of the field of psychological study. Certainly a mere study of consciousness does not exhaust the limits of the materials of this science. In this text there has been an attempt to describe, explain and relate both conscious processes and reactions. Any experimental procedure which will give information about any psychological problem is worth considering. One may define the different sciences and delimit the field of each but actually the boundaries between them are not so clearly defined as these definitions would lead one to believe. One cannot tell exactly where psychology stops and where physiology begins, for example. Thus the reader will find material from the sciences of anatomy and physiology included in this text. The sole justification for this inclusion is that this supplementary knowledge from other sciences aids one in understanding psychological problems.

The reader will find frequent admonitions for him to do something or other. The word "you" appears more frequently in this text, perhaps, than in any book you have ever read. After all consciousness is a purely personal affair and, if you wish to study consciousness, it is only your own consciousness which you can study. Thus, throughout the text, there is an effort by charts or by the presentation of problems to set up in your own mind the sort of processes under discussion at the moment. This enables you to study each of these processes in your own consciousness and to study your own reactions. If this study is conscientiously made you should come out, at the end, with a better knowledge of yourself and of your own abilities and your own defects.

A consistent effort has been made throughout to emphasize psychological fact rather than psychological theory. For example, the reader will search in vain for any reference to such a thing as the psychological theories of color vision. In many cases of conflicting theory, it is seldom that there exists a sufficient body of fact so that one can say which is acceptable and which must be rejected. As I read this manuscript, I am impressed with how many of the experiments whose results are described were completed during my own academic lifetime. It is the period since the turn of the century which has been most productive of experiment in this field. Actually some of the problems did not exist when I attended my first course in psychology.

I am also impressed with the large number of names of research workers which could have been included in the text. Actually I have avoided their use. The use of many names in such a text has the advantage of starting the student toward where he should go for further information on any topic. The use of references at the end of each chapter will accomplish this without a sprinkling of a large number of names throughout the pages—many so unfamiliar that the reader will have trouble to pronounce them and still more trouble if he tries to reproduce the spelling. To the many hundreds of investigators, living and dead, whose names I have thus submerged I offer my apologies. But scientific ideas become public and common property in spite of anything that one may do.

This text is not an attempt to write a "system" of psychology. It is merely an attempt to present systematically the facts of psychology which seem important. One finds that certain classes of material fall together into certain categories in which they may be discussed and described. Such a systematic presentation involves quite as much what one omits as what one includes. Psychological fact and theory is of such great extent that a selection is necessary for an orientation presentation. Thus the omission of any experiment is not to be considered as in the nature of a criticism of its importance. It was omitted simply because it did not seem to fit into the scheme of things.

I have no idea how much unconscious plagarism there may be in these pages. Examples of particular processes and modes of explanation become current in a laboratory and one does not remember whether one thought of them himself or whether they should be attributed to some one of one's colleagues. In any case, I hope my friends and colleagues will accept my thanks if they should find any of their "pet" examples or modes of presentation in these pages. My special thanks are due to Dr. Francis W. Irwin and to Dr. Malcolm G. Preston for their painstaking criticism of the entire text and because of their care and kindness in trying it out in mimeographed form with a group of beginning students at about the level for which this text was written.

S. W. F.

Philadelphia, Pa.

PART I

Chapter I

WHAT PSYCHOLOGY IS NOT—AND WHAT IT IS

In any summer resort or in any good sized city in America, you will probably be able to find without much difficulty a shop in front of which hangs a sign "Psychologist." All too frequently the word is incorrectly spelled. If you go inside the shop you are apt to find it fitted out in more or less Oriental fashion. The "psychologist"—either a man or woman—will greet you, and, on payment of the proper fee, will give you information regarding yourself or others, in accordance with his or her particular method. He may feel the bumps on your head; he may examine the lines on your hand; he may examine specimens of your handwriting and indeed, still calling himself a psychologist, may allegedly get into communication with the spirit of some person already dead, or he may insist that he derives his information from the position of the stars at the time of your birth or at the present moment. Or he may gaze into a crystal, or go into a trance, in order to obtain information about your character, your past and your future, and still call himself a psychologist.

If you leave this place and go to your favorite book shop, you will certainly find several works which purport to be psychological biographies or psychological novels. Your favorite fiction magazine will probably tell you that something or other happened at the "psychological moment"—although this term is less frequently used today than it was some ten years ago. If that evening you go to the theater and see a vaudeville show, it is possible that there may be a hypnotist among the acts and he is almost certain to call himself a psychologist.

It is unfortunate for psychology that this word is so popular today, for popular usage is almost invariably loose usage, and the word psychology comes to mean very much more than was originally intended. And if a term becomes popular, its use becomes profitable to all sorts of people who really have no right to call themselves by that name. Now none of the people mentioned above could really be called psychologists although some of the problems which they attack are truly psychological. These people are not psychologists, because they have never had the proper psychological training, and because they do not use psychological methods which have been tried out in psychological laboratories and found to be valid methods.

Some of the methods already mentioned are very old, the oldest is probably astrology, which purports to be a determination of character on the basis of the position of the stars in the heavens at the time of one's birth. This goes back to the most ancient times and was so widely practiced in the Middle Ages that every nobleman and king had an Astrologer attached to his court, and the king would usually make no important decision without consulting him in order to determine whether the position of the stars was favorable.

Other forms such as "spiritism" and "thought transference," which are the alleged ability to communicate with spirits, either in a trance or not, and the ability to read the minds of others, have failed in all attempts to bring them into the laboratory and produce results under strict laboratory control.

Still other forms, such as the reading of character from the shape of the head, which has been called Phrenology, are of more recent origin. Phrenology was started at the end of the eighteenth century by Franz Joseph Gall (1758–1828) and was developed and enlarged by G. Spurzheim (1776–1832). Both were strictly honest investigators who were interested in determining which parts of the brain were the specific organs for certain psychological processes. Gall localized 28 such psychological "faculties" while Spurzheim's chart shows the localization of some 35.

It may be interesting to follow through the phrenologist's reasoning in this development. They said that if a certain mental trait was very much developed in any particular individual, certainly the part of the brain responsible for it would be very much enlarged. Such an enlargement of a part of the brain would, of course, push out the adjacent part of the skull. Hence those parts of the skull which were "bumps" indicated a high degree of the underlying faculty or trait and those parts of the skull which were depressions indicated a small development of the underlying trait.

Gall's first observation was made upon three friends all of whom had marked ability in learning foreign languages. The only common characteristic which Gall could find in all three was that each had protruding eyes. Hence he reasoned that language ability must be localized in back of the eyes because the growth of this part of the brain would push out these organs. On the basis of similar observations, combativeness or love of fighting was localized just behind the ears because the skull was developed here "in the heads of brave and valiant officers, of quarrelsome students, of duelists, and of those whose greatest pleasure consisted in fighting and making themselves feared." On the other hand inhabitiveness, or love of home, was localized in the extreme back of the head which seemed to be developed in "cats and clergymen, both of whom love their fireside."

We need not enter into a lengthy criticism of phrenology. Suffice it to say that these findings have not been borne out by careful laboratory observations. Psychological analysis has shown that the fundamental belief that the mind is divided into a group of relatively independent "faculties" or traits is incorrect. Further we know that the shape of the skull determines that of the brain and not the reverse, as Gall assumed.

It will be seen, however, that the underlying note of all of these so-called psychological systems is an attempt at the analysis of human character and of human personality. This is really the fundamental problem of psychology today. Many attempts have been made to solve this problem in some such simple way as Gall's phrenology. Some years ago a rather complicated system of character analysis had a great vogue. This system took account not only of the shape of the head, but also the size and color of the various features of the face and body. If you were a blonde with a large hooked nose and small mouth, this system declared you had a certain character and personality and, if you were a blonde with a large mouth and a large straight nose you had a different kind of personality. Subsequent carefully planned laboratory tests indicated that the assumed relationships of the physical characteristics and personality are not valid. But this particular system of character analysis was supported by one of the foremost popular magazines in America and was actually used as the basis for the selection of executives by a surprisingly large number of very large industrial companies.

Psychology is certainly not such character analysis or palmistry or thought transference or phrenology or hypnosis although psychology may be extremely interested in some of these problems.

What, then, is psychology and how does it differ from some of the forms of pseudo-psychology which have already been mentioned? In the first place, psychology is a *science*. Like every other science the basic method is *observation*. This observation must be made without preconceived notions and without prejudices, of which all of us have so many. Many of these prejudices are very old and are so much a part of us that we are more or less unconscious of them and certainly not conscious of their origin. Do not most of us believe that red-headed people are all highly emotional and are easily aroused to anger; that there is something sinister about an individual unfortunate enough to be cross-eyed and that all Malays are untrustworthy (unless you happen to live in the Malay Peninsula)? One can always find examples which will confirm the prejudice if cases which do not fit one's theory are ignored.

One can find plenty of emotional red-headed people or untrustworthy Malays.

In science, the purpose of these observations is to be able to formulate some more general statement which is in the nature of a *law*. And the purpose of a law is to give one the ability to *predict*. What a scientific law really says is that we have observed that a certain thing happens in a certain way under certain conditions so that, if we can reproduce these conditions again we can predict that the same thing will occur again in the same way.

It is then obvious that one has to make a large number of observations and make records of them all, whether or not they fit one's preconceived notions of what one may expect to happen. No law can be valid or can give us a real basis for prediction unless it is based on a large number of observations. This requirement of the large number of observations is the reason why science has become *experimental* science, because an experimental procedure is really nothing more or less than the analysis of the conditions for observation and the standardization and control of these conditions so that we shall know that our second observation is like our first and that the thousandth observation will be made under exactly the same conditions as all that have preceded it and all that will come after it. The more rigidly these conditions are maintained, the more exact will be the law which is formulated from these observations.

Another advantage of experimental science has been the development of *apparatus* which is an aid in keeping the conditions constant so that they may be repeated time after time unchanged, and also in the development of other apparatus which enables the observations to be made in graphic and permanent form so that they may be studied over and over again from different points of view. Hence the experimenter may study his graphic records of observations at his leisure and he may make exact measurements of them.

The difference between simple and uncontrolled observation and experimental observation may be brought out by an example. I am sure that some of my readers would be willing to say that they have the ability to make another person turn around by staring at the back of his neck. Such a person might be willing to cite examples of times when he has succeeded in doing this. This ability, if it existed, would imply that this individual is what has been called "psychic," that is, that he has the ability in some way or other to project his mind into the mind of another person and hence more or less control his actions.

No scientist would be willing to accept this conclusion on the basis of these several successful observations—even though one does not question the fact that they were successful. So the scientist would propose putting the matter to experimental test which, of course, means standardizing and rigidly maintaining the conditions of the observation.

Let us say that the observations shall be made in a street car, or in the theater or in church and that you will stare at the head of some one, either your own or the opposite sex because there might be a sex difference in this matter. Let us say that you will stare at such a person sitting two seats in front of you because distance might have an effect. And now the scientist would impose at least two more conditions: 1. that you stare only for a given time, which may be any interval you desire but for the sake of argument let us say for ten minutes. At the end of that time you must record either success or failure—the person stared at has or has not turned. 2. The scientist would insist on a large number, in round numbers say 1,000 such observations.

At the end of this series of observations you would come out with a table of frequencies which might look like this:

Success in 600 cases
Failure in 400 cases

Clearly there are more successes than failures but does this mean that you have demonstrated your "psychic" powers. Certainly not, because we know that people do turn about without being stared at, in the street cars, in the theater or in church. If you don't believe this, just drop a book noisily in church some day. I prophesy that no one will turn about for some seconds,—one's social rules and customs will restrain so long,—but I also prophesy that within thirty seconds almost everyone within hearing will have glanced around to see where the noise came from. Hence the scientist would insist on an equal number of observations under exactly similar conditions except that now you are *not* to stare at the person under observation.

Let us imagine three sets of results after your control experiment which might read:

Result 1

	Success	*Failure*
Stared	600	400
Did not stare	610	390

In this case we would have demonstrated that staring had no effect upon the frequency with which people turned around under our experimental conditions.

Result 2

	Success	*Failure*
Stared	600	400
Did not stare	200	800

In this case the differences are so great that, on the basis of 2,000 observations, the scientist would probably be willing to believe that your "psychic" powers had been demonstrated.

Result 3

	Success	*Failure*
Stared	600	400
Did not stare	500	500

Such a result is probably the worst thing that could happen to you. In this case there is a difference in favor of your "psychic powers" but the difference is so small that no scientist would be willing to accept the demonstration without further results. He would ask you to repeat each observation—the experiment in which you stare and the control experiment in which you do not stare—some 5,000 times and, if in the comparison of each of the 5,000 observations, this difference was maintained, he would be then more ready to accept your "psychic" powers as demonstrated.

In order to facilitate such comparisons, science has developed certain *statistical methods* for the treatment of observations. Statistical methods involve the application of mathematical calculations to observations. Such mathematical treatment adds nothing to the observations themselves. It merely makes a mass of observations more understandable by expressing them in a mathematical shorthand so that a very large number may be brought into a single span of attention. By statistical treatment we can discover if a difference, such as we have expressed in our tables above, is truly significant or we can find a mathematical expression of the probability that such a difference is not due to chance factors. Many such methods of statistical calculation have been worked out for science. They are too numerous and too complicated to be discussed at this time or place.

Science, then, is observation in an effort to evolve a law and experimental science adds to this merely the attempt to control the conditions, so that all observations will be similar and that chance conditions will be eliminated or, at least, reduced to a minimum. We can declare that psychology is a science and that, for most of its problems, experimental methods have been devised to control and standardize the conditions of observation.

Thus we are now faced with the problem as to *what it is that psychology observes.* Certainly all of the forms of pseudo-psychology which we have mentioned attempt to observe some aspect of personality. Indeed the *observing of personality* is, perhaps, as good a definition of psychology as any other.

Of what then does personality consist—what are the particular problems of personality? Certainly two types of problem are obvious in this connection. In psychology we are interested in what and how a person thinks and in what and how a person acts. This gives us the first marked division in psychological problems: those of *conscious thinking* and those of *reacting*. It would, perhaps, be more adequate to say that psychology was interested in the *adaptation of an individual to an environment and to the changes effected in an individual by changes in the environment.*

Such a definition at once gives us several new terms which must be defined. We should know what we mean by adaptation, by individual and by environment. The term *adaptation* always implies a change of some sort and, in the case of psychology, it means a change in a living organism. Such a change is always effected by stimulation of the living organism. By *individual* we mean any living organism. Most psychologists are interested in human individuals but many are interested in the psychological processes of all sorts of animals from the very lowest to man. The term *environment*, as conceived by the psychologist, includes certainly everything in the physical world with which the individual may come into contact and also all factors of a social sort, which may be ideas and which therefore may have no real physical representation. One may react differently to a given physical stimulus depending upon the ideas in this individual's political or social philosophy.

The problems of reaction present little difficulty for observation. If a muscle contracts one may measure the results of that contraction in a number of ways. One may measure the extent of the resultant movement or one may photograph the movement with a motion picture camera. If one of the glands of the body secretes, which is a form of reaction in which psychologists are interested, again no difficulty is presented for observation—one may measure the amount of the secretion and what not besides. In other words, those kinds of adaptation of an individual to an environment which result in reaction present material for observation which may be measured in physical units such as length, weight, electric current and the like.

But the materials presented for observation when a person thinks are much more difficult. If you look at the page of this book you see—you are conscious of—certain black spots on a white background and this conscious experience seems to have no physical existence. If I ask you the product of 10 times 10, you can *think* the answer without reaction of any sort at all. Consciousness or mind cannot be measured directly—you cannot weigh it or measure its length or see it or taste or hear or smell it.

This distinction between *mind* and *matter* is a very old one and thousands of pages of print have been filled with definitions of each and with a description of the relations of the two, without arriving at a final solution. We can only ask that the reader will take a common sense view of consciousness. *Consciousness* always involves *awareness*, the difference between being awake and being in a dreamless sleep—the difference between being alert and being under ether. Certainly there is a difference in consciousness when one looks at a book, when one feels a pin stuck into the skin and muscle, when one is angry or when one solves a mathematical problem. It is such differences in consciousness with which psychology is interested.

One factor in the situation which is important, is that all consciousness is dependent upon the functioning of some part or other of the *nervous system* in exactly the same way that all reaction has a similar basis. Psychologists are thus forced to become interested in the nervous system of the individual studied because this part of the individual is a necessary step between stimulation, on the one hand, and either consciousness or reaction on the other.

This distinction between the problems of conscious and those of reaction give two different sorts of *psychological method.* Consciousness, after all, is a very private affair. One can observe what is going on in one's own consciousness but not in that of another individual. Every individual can describe what is going on in his own consciousness, how the results of some stimulation differ from a memory or how a memory differs from thinking. This method of observing one's own conscious processes and describing them has been called *introspection.*

In contrast with the method of introspection, certain *objective methods* have been developed for the study of reactions. Apparatus has been developed so that each different sort of reaction may be measured in terms of its extent, the stimulus necessary to set it going, the time it takes for completion and the nature of the reaction curve.

In order to differentiate the field of psychology properly it is necessary to contrast it with the fields of both physics and physiology. The difference between *psychology* and *physics* may be made clear by a purely imaginary example. Let us suppose that a very large tree crashes to the ground in the center of a forest and that there is no living thing within 100 miles of the tree. The same question is asked a physicist and a psychologist: "Did the tree make a noise when it fell?" The physicist would answer: "Yes, certainly, the tree made a noise because it set up certain waves in the air which are the *stimulus* for sound." The physicist is interested only in the physical stimulus which might cause conscious processes or reactions. On the other hand, the psychologist would say: "No, the tree in falling made no noise. It is true that the fall set up an adequate auditory stimulus but, inasmuch as it neither aroused consciousness nor lead to reaction in any living organism, there was no noise. Noise is not produced unless there is an ear to hear it." The psychologist is interested in what the physical stimulus does to the individual.

This difference between physics and psychology may become clearer if you observe figure 1. Are the lines marked *AB* and *CD* the same length? Certainly at first glance the line *CD* seems longer than *AB* and, if you continue to look at the lines this difference does not disappear.

Probably you will have to measure the lines to assure yourself that they are actually the same length. As a matter of fact, their physical lengths are identical. This is a clear demonstration that there need not be exact correspondence between the physical stimulus and its psychological effect.

Nor need identical physical stimuli lead always to exactly the same reactions. If you are in a railway station and you hear the bell of a locomotive of a train standing there, you will react in one way to this stimulus if you are going on the train. But you will react in a very different way if you are driving a car approaching a grade crossing and hear the identical locomotive bell. So much then for the distinction between physics, which is solely interested in the stimulus, and psychology, which is interested in the effects, either conscious or reactive, of this same stimulus when it impinges on a living organism.

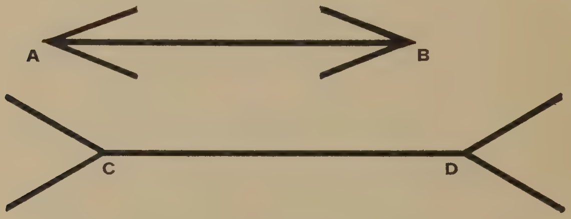

FIG. 1

And what, then is the difference between *psychology* and *physiology*, when both of them are interested in the effects of stimulation of a living organism. Physiology is interested in these effects of stimulation upon only single organs of the body. It is interested in the effect, at one time, upon the heart or, at another time upon the eye or the liver. Psychology, on the other hand, is interested in the effects of stimulation on the total organism. At times it has been rather difficult to draw an exact line of differentiation between psychology and physiology. With regard to certain problems the methods and the points of view are very similar. Certainly today some physiologists are doing excellent psychological experiments and some psychologists are doing excellent work in experimental physiology. This is particularly true of those experiments of a neural nature—those which have to do with the nervous system. There is a similar difficulty today in drawing a sharp line of demarcation between physics and chemistry.

Having established the field of psychology as being interested with problems in the effects of stimulation on the consciousness or reactions of the total organism and thus having differentiated it from the fields of both physics and physiology, it seems worth while to enumerate some of the actual specific problems in which psychology is interested. In the first place, it is interested in the simpler conscious processes of how the organism obtains knowledge of the external world. It is interested in seeing, hearing, tasting, smelling and the like. It is interested in how these experiences are later recalled in memory. It is interested in how these remembered experiences are organized in thinking and imagination, which are examples of the more complex conscious processes. On the reaction side, we shall be interested in the simpler reactive processes, such as reflex and instinct, as well as in the more complex reaction processes, like emotion and volition and the formation of habits.

And each of these problems may be approached from different points of attack We may be interested in the normal adult human or we may be interested in how widely normal adult humans may vary from one another. Or we may want to know how the child differs from the adult and what are the stages of development in this growth. Or we may want to compare the conscious and the reactive processes of the normal man with one who is insane or otherwise abnormal. We may want to compare several animals with man or with each other and determine how similarly or how differently they react in a given stimulus situation. All of these are special approaches to the problems of psychology and each will give special and additional information toward the understanding of our conscious or of reactive behavior. And besides all this, we want to find an explanation of consciousness and of reaction in all of their phases, in terms of the nervous system, wherever possible.

Not many years ago a very important field of *applied psychology* was developed. Growing out of a study of individual differences, especially as regards intelligence, Lightner Witmer (1867– ——) in 1896 founded what he has called the Psychological Clinic. In such a clinic individuals are examined who present some difficulty or other in individual adjustment to their environment and the psychologist makes an analysis of his personality to determine his specific abilities and defects and so form a basis for giving advice in regard to a better adjustment in school, in business, or in life. The importance of this work was recognized by education, and with the rapid development of psychological methods for determining intelligence, it forms the basis of much of the present day trends in educational procedure. Probably most of my readers who are still studying have, at one time or another, been subjected to such a psychological examination or test. Once the validity and usefulness of such psychological tests had been demonstrated in regard to intelligence, others were devised to study such personality phases as interests, emotional reactions and many other processes.

The clinical method in psychology has been extended to such problems as the analysis and diagnosis of defects of speech, of many of the subjects of the school curriculum and, more recently, in personality analysis, leading to vocational guidance and selection in industry as well as educational guidance. But a word of warning here! Psychology is not in a position today to tell whether an individual is best fitted to become a carpenter or a plumber; a teacher of French or a teacher of German. Such fine distinctions of analysis are still far beyond present day psychology because methods have not yet been developed to determine them. But, on the basis of a complete and thorough clinical examination today, a trained psychologist in most cases can tell whether an individual has the ability to study and practice medicine, let us say, or whether he had better go into one of the manual trades.

The development of the clinical method with the diagnosis of personality, and the possibility of advice in regard to individual development, is really the ultimate reason for psychology. Because, if psychology is a study of personality in relation to the organism's environment, then such a study should be able, in each individual case, to determine what sort of environment best fits each individual so that he may make the most of his particular abilities and be least handicapped by his defects. In this way, the world will become a better place to live in.

Such a development of psychology did not happen suddenly. It did not spring ready formed from the brain of any single man. The story of the slow emergence of psychology as an experimental science will be briefly told in the next chapter.

QUESTIONS

1. In what sense are Astrology, Palmistry, Phrenology, Spiritualism, thought transference or hypnosis of interest to Psychologists.
2. How does Psychology differ from the pseudo-sciences of human personality?
3. What is the subject matter of psychology?
4. What is meant by consciousness? By reaction?
   What particular difficulties do they offer to research?
5. What is the difference between psychology and physiology?
6. In what way has psychology been applied to practical problems?

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CHAPTER II

A BRIEF HISTORY OF THE DEVELOPMENT OF PSYCHOLOGY

Man has been interested in psychological problems as long as he has been thinking. Certainly one finds a discussion of such problems as those of thinking and acting in all of the earliest writings extant. In ancient Egypt, India, China and Greece very elaborate psychological systems were developed in the earliest times. It is a curious fact, however, that the inheritance of modern psychology seems to be entirely and solely traceable to ancient Greek thought.

The story of this development can be told in outline in a few sentences. The word *psychology* comes from two Greek words,—the last three syllables (ology) meaning *science* and the first syllable (psyche) literally meaning *breath*. So the original definition of psychology was the *science of breath*. But the ancient Greeks identified the breath with the soul. They observed the very obvious fact that when the breath left the body the soul had departed and indeed, on a cold day, one might actually see the last breath depart from the body. As the lungs collapsed at the moment of death, it appeared as a cloud which, under emotional excitement, might be interpreted as having the shape of a small human body. In some medieval pictures of a person dying just such a human-shaped cloud is seen issuing from the mouth, depicting the departure of the soul. Hence the early Greeks, when they defined psychology as the science of breath really meant the *science of the soul*.

Under this definition, the Greeks were interested in the problems of consciousness, of the bases for different kinds of reaction and especially in the bases for ethical actions. First, because the definition in terms of soul failed to describe the kinds of problems in which they were interested and, secondly, because in early Christian times, the soul received a very definite religious connotation, psychology gradually became redefined as the *science of mind.*

But this definition offered difficulties as human thought developed. For example, one of the persistent problems of philosophy is the failure to *prove* the existence of a mind other than your own. Your own mind you can observe. Such observation of your own mind goes by the special term *introspection.* But the mind of another you have to accept either on the testimony of that other individual or by analogy—neither of which methods constitutes proof of its existence. And gradually again psychology became redefined as the *science of consciousness.*

But the term consciousness presents the same sort of difficulties as had the term mind. After all, consciousness is a very individual thing. Each person may observe his own conscious processes, he may describe what is going on in his own consciousness, but he can never be sure that some other individual completely and correctly has a similar conscious process resulting from this description. Add to this the fact that psychologists, in these last few years, have become more and more interested in reaction and, indeed, in those sorts of reactions in which no consciousness is involved. It was therefore natural that psychology should receive its last definition as the *science of behavior.* In this definition, the emphasis is on reactive processes and it eliminates such philosophically objectionable terms as consciousness, mind or soul.

This development can easily be remembered by the sentence written by some psychological wag, which says that: "Psychologists first lost their breath, then they lost their soul, then their mind and now, with the developing interest in reactions, they are rapidly losing consciousness."

On the basis of this outline, it seems worth while to fill in some of the details of this development. To begin, one may contrast the two important Greek systems of *Plato* (B.C. 427–347) and of *Aristotle* (B.C. 384–322). Both systems are primarily an attempt to explain the reasons and the mechanisms for an ethical and moral life. It is also interesting to note, in both cases, that there is an attempt to relate conscious and physiological processes—an attempt to explain mind so far as possible in terms of body.

Plato starts by asserting the existence of a soul which is located in the head and which contains all wisdom, has clear ideas and exerts the final control over all actions. This he calls the rational soul. There is another or irrational soul which has two parts. The higher or nobler part is located in the heart and the lower part is the bearer of the appetites and the baser passions.

But Plato's principle contribution, or at least the contribution which has had the greatest effect on psychology, has to do with the problem of how we obtain knowledge or ideas. At first glance, it would seem that all knowledge comes to us through the senses and Plato admits that these do make a contribution. But he insists that the clear and important ideas are ones that are in the mind from the beginning. They are really independent of experience and, apparently, are as much a part of the soul as the arms or head are a part of the body. All sense experiences are corrected by these original ideas with which one is born. Because we have these ideas from birth they have been called *innate ideas*. For Plato, knowledge was little more than a reawakening of ideas which were in the soul at birth.

Aristotle's system is in very sharp contrast in this respect with that of Plato. Aristotle makes sensory experience the entire basis of knowledge. The senses are never wrong. If errors occur, they are caused by what the mind does to this sensory experience. There are five senses, seeing, hearing, taste, smell, and touch. Each responds to appropriate stimulation from the outside world. Above these special senses is what Aristotle called the "common sense" which coördinates the individual sensations, which are the raw materials of knowledge, by filling in gaps and by harmonizing experiences. Memory is merely the bringing back into consciousness of these former experiences whether the recall be during the waking life or during sleep as dreams. Emotion and action are less important for Aristotle than they are for Plato but action is again made dependent on thought. All of this is coördinated with a curious physiology. The seat of the soul is in the heart. Food is distilled under the influence of the heat of the heart and, when acted upon by air in the lungs, it is further distilled into what are called animal spirits. These animal spirits pass through the nerves, which are conceived as hollow tubes, and cause both consciousness (when they reach the heart) or reaction (when they reach the muscles). In this physiological system, the brain is conceived as a cooling system when the animal spirits become too overheated.

There is much in the ideas and the terminology of Aristotle's system which has a popular modern twang. Indeed, one can say, that the popular psychological system of today had its origin in the mind of Aristotle. The five senses, the dependence of memory and thought and action on sense experience are still accepted today by the man on the street. Such terms as "animal spirits" and "common sense" had their origin with Aristotle even though the original meaning has been entirely changed and lost.

But the Greek systems of Plato and Aristotle present two answers to the problem of the origin of knowledge and of ideas which remained important for many years in the history of psychological thought. Aristotle was a very great mind and for the remainder of the Greek and Roman periods his system prevailed. Thinkers merely amplified and modified and corrected this system for some centuries. Soon the seat of the soul was changed from the heart back to the brain. *Galen*

(A.D. 130–200) developed the still popularly accepted system of four temperaments, sanguine, phlegmatic, melancholic and choleric—each based upon a humor or secretion from some organ of the body. But surprisingly little advance was made in the development of psychological ideas in this period of some six hundred years following Aristotle.

The next important contribution to psychological thinking was motivated by the rise of Christianity and its new concept with regard to the soul. It was now more important that souls be saved than studied. The early Christian point of view was crystallized by *St. Augustine* (354–450) whose writings became authoritive for the Church. Augustine accepted basically the system of Plato rather than that of Aristotle for two reasons. In the first place, Aristotle was the great "pagan" thinker and hence his ideas could not be accepted by the Christian Church and, secondly, Plato's concept of "*innate ideas*" was far more harmonious with the early Christian concept of the soul. Sense experiences were still recognized and Augustine even accepted Aristotle's idea of the "common sense" but above all of this he insisted that there are certain ideas implanted with the soul at birth which mold all sensory experience and to which all sensory experience must conform. All action originates in the soul and no action is spontaneous. Perhaps the greatest contribution made by Augustine is the concept that all classes of mental processes have each its own basic mental "faculty." The soul possesses such faculties as sensing, memory, imagination and will.

One cannot overemphasize the importance of the psychological system of Augustine although, like that of Aristotle, it tended to stifle original thought and its influence tended to greatly retard the development of psychology because of the great authority of this author. As in the case of Aristotle for the subsequent Greeks, the writings of Augustine became the model of the subsequent Christian philosophers. So, for nearly eight hundred years, we find thinkers enlarging and modifying the basic Augustinian system. And during this time Aristotle became lost to European thought—all Greek works were destroyed wherever discovered.

This condition lasted until the time of *St. Thomas Aquinas* (1225–1274). His contribution consisted in a harmonizing of the system of Aristotle with the still prevailing doctrines of Augustine. With regard to the acquisition of knowledge Aquinas again threw the emphasis upon sensory experience as supplying the raw materials for thinking. These were coördinated by the common sense which gave to them their general characteristics such as extent or duration. And then reason, with its innate ideas, stamped upon these experiences the final seal of truth. In the field of action both will and action were dominated by the intellect which must always choose between several alternatives.

Aquinas was only part of a movement leading to renewed interest in scientific and philosophical matters. In this period we find Roger Bacon developing a theory of science in which he pleads for a return to direct observation; Gutenberg inventing printing; da Vinci developing the laws of art and making considerable contributions to physics and to anatomy; Copernicus giving us not only a new astronomy but also a new theory of the universe; Vesalius remaking human anatomy, and Galileo, Kepler and Newton changing the basic concepts of physics. It was only at this time that the different sciences began to develop independently. Before this any philosopher felt competent to write about all of the universe and philosophy was divided into only two parts—physics, which was concerned with all material things, and metaphysics, which was concerned with everything else. Quite obviously psychology, which was the study of the soul or mind, was a most important part of metaphysics.

This movement led to the development of scientific method, most important for all of the sciences, but especially for psychology, which one finds crystallized in the writings of *Francis*

Bacon (1561–1626). In previous thinking, the chief method which had been employed had been called deduction—one started with certain principles such as a particular concept of the soul and then proceeded to write a logical system from this basic concept. Bacon insisted on the *inductive method,* which is really only a return to Aristotle, and which consists merely in observing particular experiences and then comparing them to eliminate accidental differences. The result of such a comparison, if one's collection of experiences is exhaustive, must lead to a scientific law. It is obvious that such a method is basic for experiment and, indeed, experimental science cannot develop without its acceptance and without regard and strict adherence to its principles. Experimental science, as compared with general observation, merely involves the control of the original experiences in order to reduce the number of accidental errors.

The first psychologist to attempt to use Bacon's inductive method was *Thomas Hobbes* (1588–1679). In his texts, sensations and the resultant memories are strongly emphasized as the basis for thought and much space is spent in trying to make a distinction between these two sorts of conscious processes. In this discussion, much emphasis is given to the connections between ideas and, with this, we have the beginnings of the consideration of *association of ideas* which so colored the thinking of English psychologists for the next several hundred years.

Utilizing the new method of induction, *John Locke* (1632–1704) made an exceedingly important psychological contribution which came very near to having an experimental basis. He questioned the innate character of ideas and he reasoned thus. If any idea is truly innate, implanted into man as part of his soul, we should then expect to find this idea in every human mind. So he drew up a list of ideas which various people had declared were innate and he questioned educated adults, children, insane people and (this being the period of great British territorial expansion) he had explorers and missionaries question primitive peoples with whom they came in contact. The reports indicated that no single idea was common to all of these groups. Hence Locke concluded that there were no such things as innate ideas whatsoever. Instead he insisted that human consciousness was a blank tablet (*tabula rasa*) at birth and on this blank consciousness sensory experience wrote its story. The emphasis was thus again thrown strongly upon individual experience, through the senses, where the emphasis had been thrown in the system of Aristotle. The Platonic concept of innate ideas has not seriously appeared in the literature of psychology since that time.

But if ideas are to be conceived as a matter of individual development as the result of sensory experience, it then becomes necessary to explain, in some detail, how this development takes place. For the particular idea of visual space, such an explanation was contributed by *George Berkeley* (1685–1753). Berkeley not only explained the basic anatomical mechanism for such ideas of seen space but indicated how they developed as well. *David Hume* (1711–1776) attempted to explain the development of other and more complex ideas and, in this connection, he made great use of the concept of association of ideas—how several ideas present together in consciousness might combine and thus create a new idea by that combination. For the next hundred years, this concept of the association of ideas dominated British psychological thinking.

Everything came to be explained in terms of association of ideas and the concept was carried to ridiculous lengths especially in the hands of *James Mill* (1773–1836) and *John Stuart Mill* (1806–1873). An example of what may happen if such an idea is pushed to an extreme may be found in the following short quotation from James Mill:

> "Brick is one complex idea, mortar is another complex idea: these ideas, with ideas of position and quantity, compose my idea of a wall. My idea of a plank is a complex idea: my idea of a nail is a complex idea. These united with the same ideas of position and quantity, compose my duplex idea of a floor. In the same manner, my complex ideas of glass, wood and others, com-

> pose my duplex idea of a window; and these duplex ideas united together compose my idea of a house which is made up of various duplex ideas. How many complex or duplex ideas are united in the idea of Furniture? How many more in the idea of merchandize? How many more in the idea called Everything?"

And it would seem that the reason for this exaggeration lies in the fact that these philosophers had already abandoned the inductive method and returned largely to that of deduction. The concept of association of ideas remains an important one in modern psychology but now we know both the facts and the limitations of this concept on the basis of experimental results.

This discussion must turn back in time to the work of *Rene Descartes* (1596–1650) to pick up another type of problem which has been a persistent one both in philosophy and psychology. Descartes for the first time clearly differentiated mind and matter (or the body) although the dualism had been present or implied in human thinking for some two thousand years before this. Descartes defined matter as that which occupies space and mind as that which is conscious or that which has the ability to think. The problem would not be so important except that Descartes and many thinkers since his time, have attempted to explain the *relationship* between mind and body. Descartes' own explanation involved a mutual effect of each on the other—mind can affect body and body can affect mind. It will at once be realized how this dualism and the solutions of the relations between the two factors will affect the problem of *free will* as emphasized in Christian theology.

Many and various attempts have been made to resolve the difficulty. Descartes and others have insisted on the mutual interaction. Some have denied the existence of mind (*absolute realism*); others have denied the existence of matter (*absolute idealism*). Still others have insisted that mind and matter are the same substance but viewed from different aspects as was argued by *Benedict Spinoza* (1632–1677) Dual aspect or identity theory. Still others, as did *Leibnitz* (1646–1677), insist that mind and body are different entities but that there is no relation between them other than the fact that somehow they were started off together so that whenever a certain event happens in one of them a corresponding event happens in the other. But a *causal* connection between the two, either of mind on body or of body on mind, is denied (Doctrine of pre-established harmony or psychophysical parallelism). The problem of the relation of mind and body is considered much less important today and is relatively ignored by modern psychologists. Still its historical importance cannot be minimized, inasmuch as its discussion gave great emphasis to the idea of consciousness and to the possible relation of consciousness with the body and especially with the nervous system. One can safely say that philosophically the problem of the relation of mind and body is no nearer actual solution than when it was so clearly formulated by Descartes.

No historical statement of the development of psychology would be complete without mention of *Immanuel Kant* (1724–1804), although his influence on this development was largely negative. Kant's philosophical contributions, important as they are, need not be mentioned here. These contributions were largely of a philosophical nature and were aimed at a criticism of the work of Locke and his successors, Kant insisting that the mind supplied certain *apriori* forms which systematized the sense experience which must, in the nature of the case, be chaotic. He was particularly concerned with the nature of these *apriori* forms, which presents really the theory of innate ideas in another form and with another setting. Kant also added *emotion* as a distinct class of mental processes to the already accepted classes of intellect and will. Of great importance was his insistence that the soul or mind, conceived as an entity, was not a proper subject for psychological study but that psychology should consist of an empirical study of mental processes and human reactions. And finally, Kant, in a discussion of science in general, set up the criterion of exact measurement. Nothing could be called a science unless its subject matter could be measured exactly and accurately. Inasmuch as mental processes—thought and sense experiences and emotions—could never be so exactly measured, psychology could never become a science. And Kant's writings had authority for many years, in Germany in particular, so that his pronouncements were accepted almost as dogma.

Part of the answer to this criticism was made by *Johann Friedrich Herbart* (1776–1841) who defined psychology as a science grounded on empirical experience, on metaphysics and on mathematics. He then develops this definition by proceeding to apply the mathematics of physical mechanics to the concept of the association of ideas in order to explain how one idea may aid another into consciousness or, in another situation, how two ideas which are opposed to each other, may tend to mutually exclude each other. In actual practice, such a mathematical application cannot be made because no one can measure the strength of any particular idea in any given direction. But, at least, with Herbart the emphasis is upon empirical observation with the hint of mathematical application and the insistance that psychology is a science.

Actually, the solution to Kant's criticism came not through philosophy at all but through the science of physiology. For many years some physiologists had been interested in problems of sensory experience and the correlation of these sensory experiences with what was happening in the sense organs and with other parts of the nervous system. Such an experimental physiologist was *Hermann Lotze* (1817–1881) who did some interesting experiments on the sensations arising from the skin but who also had broad systematic and philosophical interests. As a result of this latter interest, he wrote a book (1852) to which he interestingly enough gave the name "Medical Psychology." The book was important because Lotze included all that physiology had to offer in the way of observed sensory facts, because he applied a physiological explanation to psychological processes wherever possible. Thus he definitely tried to carry a non-supernatural explanation of mind as far as it was possible with the then known facts. Here at last we have evidence that at least one small part of psychology—the simpler conscious experiences from the stimulation of the sense organs—could be submitted to experimental study.

Of course, Lotze had a background of established experimental physiology. Before this time, we have the work of *Charles Bell* (1774–1842) who differentiated the sensory and motor nerves of the central nervous system. And there was already extant the text on human physiology by *Johannes Müller* (1801–1858) published in 1833 and 1840, in which he collected all of the known experimental facts about the different kinds of human physiological processes. This book defined the field of physiology and established it as a separate experimental science. In this connection it is interesting to note that Johannes Müller included one section entitled "Of the Mind" which consists of only 82 pages. At this time, then, all that was known about psychology, except the sensory processes which are treated in another section, could be included in 82 pages.

One cannot leave a historical treatment of the physiologists without mention of *Hermann von Helmholtz* (1821–1894) although his life extended far into the experimental period in psychology. He contributed very largely to the problems of vision and of hearing by both collecting and interpreting the results of others and by supplying very many important facts and methods by his own experiments.

But still Kant's criticism that psychology could not become a science really remained unanswered. No one had yet accurately measured conscious processes. The final solution of this problem was accomplished by *Gustav Theodor Fechner* (1801–1887). The publishing of this discovery is to be found in a book printed in 1860. Fechner points out that measurement can never be possible until one has established a *unit of measurement*. One cannot measure any distance until he has decided on the foot or the mile or the meter as a unit; one cannot measure temperature until the thermal degree was established. And the unit of measurement is always perfectly arbitrary—one can divide the temperatures between the freezing and the boiling point of water into 100 units, as in the centigrade thermometer, or one can divide this same range into 180 units, as in the Fahrenheit scale.

As the result of a consideration of his own and former experimental work, Fechner proposed the *just perceptible difference* as the unit of measurement of conscious processes. If one starts with two stimuli that are the same, the subjects would report them as arousing similar sensory experiences. If one of them is then increased or decreased, keeping the other constant, the subject will finally arrive at a point at which he reports that the conscious experiences are different. The *physical* difference between these two stimuli, which just arouse a conscious difference, became for Fechner the measure of the just perceptible difference. And one can establish the zero point of conscious experience by starting with a stimulus which is too weak to arouse conscious experience and then increase the intensity of the stimulus until conscious experience is first aroused. It was possible, then, on the basis of experimental evidence to say that this given conscious experience was a given number of just perceptible differences above the conscious zero, in exactly the same way that we can say that this book is a given number of inches tall.

Here then was a new unit of measurement and Fechner devised a number of experimental methods by which this unit of measurement could be determined. To this experimental field he gave the name of *psychophysics* and by it he hoped to be able to solve the problems of the relation of mind and body as formulated by Descartes. In this he failed, but the methods devised by Fechner and the unit of measurement conceived by him still constitute a very important part of the basis of experimental psychology. It is true that the measurement is

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an indirect one—we measure mind not directly but indirectly in terms of physical measurements of the stimulus which arouses a certain kind of conscious process.

And now the stage is set for the establishment of psychology not only as a science but as an independent science which has its basis in the use of the experimental method. Johannes Müller established *physiology* as an independent experimental science by defining its field, its problems, its methods and its results in a book published in 1840. *Psychology* was established as an independent experimental science in the same way by a book published by *Wilhelm Wundt* (1832–1920) in 1874.

Wundt had training in medicine and then became especially interested in physiology. For a time he was an assistant to Helmholtz and he performed a number of experiments which had to do with the rate of transmission of an impulse along a nerve and with certain facts of sense experience. Indeed he had the then known facts of physiology at his command, having already written a text book on that subject. And in one of his earliest papers, Wundt actually uses the term "experimental psychology." Aided by this background of experimental science, Wundt was nevertheless at heart a philosopher and a systematizer. Besides this Wundt wrote easily and voluminously, during his productive period of 68 years he is credited with writing some 491 items with a total of well over 50,000 pages.

Wundt clearly took the view that psychology was faced with a number of problems which were essentially its own and which did not conflict with the field of any other science. All of these special problems clustered about the central problem of consciousness and they may be enumerated as follows. Psychology is concerned (1) with the analysis of conscious processes into simpler elements; (2) with the combination of these elements into the more complex processes; (3) with the relation of consciousness to reaction and (4) with the relation of all of these to neural and to other physiological processes. He pointed out that practically all of these problems could be brought into the laboratory and subjected to experimental treatment. And finally all of this was to be explained in physiological terms so far as possible and a supernatural explanation of any part of it was to be avoided. Wundt had already at hand much apparatus which he could borrow from physiology as well as the statistical methods for treating his results already developed by Fechner. New apparatus was rapidly invented.

Inasmuch as this new science centered around the problems of conscious processes, its distinctive method was that of *introspection*—the examination and report on one's own conscious processes. Of course, Aristotle and all of his successors had said this—there is nothing new in introspection. But under Wundt one was to introspect this conscious process induced at the will of the experimenter under experimentally controlled conditions and not under the haphazard conditions of daily life. One curious aspect of the situation is that Wundt insisted that his experimental approach was entirely adequate for a study of the simpler conscious processes but was not adequate for the study of the more complex conscious processes involved in thinking. It was alleged that thinking problems could not be attacked directly but only indirectly by a study of the products of thought—by a study of social relations and other recorded products. Hence Wundt's analysis of the problem of thinking is to be found in a number of large volumes in which are discussed such topics as language, myth and religion, law, art, history and business.

This book, The Principles of Physiological Psychology, which is definitive for psychology, was published in 1874 and at once attracted widespread attention and interest. The next year Wundt was invited to become Professor of Philosophy at the University of Leipzig. It was only much later that separate professorships of psychology were established. In 1879 he founded the first laboratory of psychology ever established.

At once matters moved rapidly. Wundt's new laboratory attracted many students and very soon a great variety of experimental psychological problems were in progress. Students came to Leipzig from all over the world to get this experimental training in psychology—many went there from America. These students received their training and then went back to their own countries and established psychological laboratories of their own. Psychology was very soon established as an experimental science capable of producing quantitative results which completely met the objection raised by Kant.

One cannot follow in detail this experimental development both of method and of fact. The present volume will present, in systematic rather than in chronological order, some of the more important aspects. How rapid was this growth may be envisaged from the fact that the first edition of Wundt's book in 1874 contained 870 pages—and much of this was theoretical discussion—while the sixth edition in 1908 required three large volumes with a total of 2,317 pages in which the proportion of theoretical discussion was much reduced. During the intervening 34 years there had been a great accumulation of fact which has increased in volume still more since that time.

In 1885, only fifteen years after Wundt had said that the more complex problems of consciousness could not be brought into the laboratory, *Hermann Ebbinghaus* (1850–1909) printed a little book which is, in fact, a report of a quantitative study of memory and of forgetting. In this he shows how Fechner's methods of exact measurement may be applied to at least one of the more complex conscious processes. Thus experimental method had been brought to bear on all of the problems of psychology—complex as well as simple. Ebbinghaus' book is perhaps one of the most important ever written, not only because it extended the field for the application of experimental methods to psychological problems but also because of its importance in initiating an experimental approach to the problems of learning and forgetting which comprise such a large part of experimental education.

Out of the mass of experimental work collected since the establishment of psychology as a science, there has grown up a number of systematic points of view concerning the interpretation of this data, in regard to what is considered the proper and adequate method and in regard to the limiting of the field of research. These differences in systematic point of view have been crystallized into the several so-called "schools" to the tenets of one or another of which many psychologists subscribe.

Of these, the viewpoint called *Structuralism* may be first considered because it is chronologically the oldest and because it is essentially the systematic point of view of Wundt. Structuralism obtained its clearest expression in the hands of *Edward Bradford Titchener* (1867–1927). For him psychology was concerned with an analysis of complex conscious processes into their elements and (2) with the laws of the combination of these mental elements into the more complex conscious processes. In what seems to be a rather grudging fashion, Titchener admits a third problem, namely, the relation of the simple and complex conscious processes to the physiological processes of the nervous system. He states that the method of all science is observation and, if one observes conscious processes, one must employ the method of introspection. Introspection, then, is the fundamental and basic method for psychology and all other methods are purely secondary and, at best, can only verify the results of introspective observation. And most important in the development of the introspective technique is the determination of a standardized terminology so that anyone with these terminological distinctions at their command may interpret any introspective report.

One finds in Titchener's texts, therefore, a full discussion of simple and complex mental processes—because here the introspective method is adequate—but he has relatively little to say about human reaction and practically nothing to say about animal reaction because here the introspective method is not adequate. One cannot train an animal to introspect in terms of one's special vocabulary. Furthermore, Titchener is most insistent that psychology is a science and he completely rules out all practical application as not truly scientific inasmuch as such applications are in the nature of an art.

The result of this attitude is a very restricted and very academic kind of psychology. After all Titchener's kind of report can be made only by an individual trained in introspective terminology. Hence, strictly, this can never be more than the psychology of a trained normal adult human because of this limitation. The untrained, the abnormal, the child and the sub-human subjects are excluded because they cannot introspect. Thus there can be no child or animal or abnormal psychology therefore. And furthermore there can be no form of scientific applied psychology because such an application is an art and not science.

In contrast to the narrowness of the field as defined by structural psychology, the greatest broadening is to be found in *Functionalism* which had its beginnings in the work of *William James* (1842–1910) and which received its more exact definition at the hands of *James Rowland Angell* (1869——). While Structuralism sought primarily to answer the problems of the nature of consciousness, Functionalism seeks the answer not only to this problem but also that of the place and function of conscious in reaction and in the adaptation of the individual to his environment. Thus Functionalism is interested in those reactions which do not involve consciousness whether these be in man or in animals; it is interested in the development of consciousness both in the individual and in the animal scale and it is interested in the differences between normal and abnormal reactions.

As a result of this definition of field, Functionalism of necessity admits experimental methods other than introspection. More objective methods of experimenting are necessary for problems of reaction without consciousness: for the study of reactions of infants or of animals. Also the functionalists are free to admit all sorts of practical applications of psychological principles and methods to business and industry, to education and the like—in the hope that these applications will give some additional information regarding psychological processes. Since the formulation of the Functional principles, the experimental emphasis has been more and more toward the use of objective methods, so that today little distinction can be made between some psychological problems and some of those of strict physiology. Indeed some of the most important physiological experiments in the last few years have been performed by psychologists with psychological training and background and working from a psychological point of view.

Another "school" which has been developed is that of *Behaviorism*, expounded by *John Broadus Watson* (1878——) whose training was in the point of view of the Functional school. Watson did important work in animal psychology. He had observed reactions of the rat in various situations and he was impressed with the validity of the objective methods for the observation of reactions. He was further impressed by the variability of results obtained by the introspective method and with the apparent mysticism which surrounded the concepts of mind and of consciousness. As a result he suggested that psychology should be concerned solely with problems of reaction or of behavior and that the methods employed in psychological experimentation must be purely objective. If one can observe the reactions of the rat when subjected to a given stimulus, why not do the same with the human. In order to eliminate all problems of consciousness from psychology, Watson had merely and simply to deny its existence. And if consciousness does not exist, obviously, the introspective method is unnecessary and meaningless. From this point of view, one may observe the reactions of any organism whatsoever under stimulation. For a scientific study one must have knowledge of three factors: (1) the stimulus; (2) the nervous system and the reactive mechanism which is being stimulated; and (3) the reaction itself. Watson expressed the hope that if we had complete knowledge of any two of these factors that we could predict the third. From this point of view the problem of thinking presents difficulties inasmuch as this seems to many of us to be a highly conscious process and one not necessarily accompanied by reaction. This problem Watson solved, and thus saved the problem for Behaviorism, by declaring that thinking was nothing more or less than speech which was not vocalized, words not actually said aloud.

Still another point of view is that expressed by *Gestalt* or *Configurational* psychology, expounded by three individuals: *Max Wertheimer* (1880———), *Wolfgang Köhler* (1887———) and *Kurt Koffka* (1886———). Gestalt is a system in protest to Structuralism, to Functionalism and to Behaviorism. Its adherents insist that much has been lost by the analysis insisted upon by all of the older points of view. They say that our consciousness of seeing a table is not the consciousness of seeing the top and the consciousness of seeing each leg separately but of the complex table in a single and unanalyzable configuration. And a complex reaction must be considered and should be studied as an unanalyzed whole not as the separate individual muscle contractions of which it is composed. From this point of view they have simplified our concept of the more complex reactive and conscious processes. And they find uniformity throughout the universe: physical configurations set up physiological configurations which in turn lead to conscious or to reactive configurations.

The last of the points of view has been called *Dynamic* psychology and is best exemplified by the work of *Sigmund Freud* (1856———). Freud is a physician interested in mental disease and his psychological theory is incidental and explanatory to his observations on mental abnormalities. The system is a mystical one, the details of which need not concern us, but which makes great use of the concept of a subconscious mind.

Consciousness, as the rest of the psychologists have conceived it, becomes relative unimportant for Freud. The emphasis is on what happens to ideas which are forced to remain in the subconscious mind—where they have been "repressed" by what he calls the "censor"—and of the effect of these ideas on consciousness and on reaction. All former psychological methods, introspective or objective, have to be discarded because they can give no information in regard to the subconscious mind. As his principle aids in this study, Freud places a reliance in dreams and in hypnosis both of which, he believes, allow one to gain at least indirect information about the subconscious mind.

We shall discuss Freudian *psychoanalysis*, as it has been called, elsewhere in the present text. It is mentioned here so briefly simply because of its present popular importance and because it has contributed to the development of psychology by emphasizing the problems of motive and of motivation. But Freud's system is so markedly out of step with other psychological thought, because of its mystical character, its reliance upon abnormal rather than normal consciousness, its emphasis of the subconscious mind, its reliance upon methods not elsewhere validated and its failure to explain its important and basic concepts in physiological terms, that further treatment seems unnecessary except as it applies to the particular problem of motivation.

What should one do in this complicated situation with differences in points of view, in method and in systematic interpretation? What seems reasonable, and this attitude will be followed in the present text, is to utilize any viewpoint or method or result which gives light on the particular problem under discussion. Each of the systems seem most adequate to a particular type of problem, as for example, Behaviorism for reactions not involving consciousness, and we may accept without hesitation the methods and results from that point of view on such a problem. But each system seems far too narrow to cover the entire field of psychological interests or, at least, to emphasize one particular type of problem that it practically excludes others. Hence we shall seek psychological light from whatever quarter we may find it.

QUESTIONS

1. Contrast Plato and Augustine with Aristotle and Aquinas in respect to their psychological beliefs.
2. What is the contribution of Francis Bacon to psychology?
3. Discuss the history of Associationism through Hobbes, Locke, Hume, Berkeley, and the Mills.
4. What is meant by the Mind-Body problem? What were the contributions of Descartes, Spinoza and Leibnitz to this problem?
5. On what grounds did Kant object to the possibility of psychology being a science?
6. What was Fechner's contribution to experimental psychology?
7. What are the necessary requirements for the establishment of a quantitative science?
8. What was Wundt's statement of the problem of psychology?
9. How did Ebbinghaus transcend Wundt's limitations on Psychology?
10. How did Titchener limit the possibilities of psychology?
11. What possibilities did James and Angell open with the development of Functionalism?
12. What is Watson's relationship to the psychology of reaction?
13. What changes in systematic viewpoint does the acceptance of Freud's work involve?
14. What is meant by a "school" of Psychology?
15. From the practical point of view what is the most profitable position to take in the study of psychology?

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PART II. THE SIMPLER CONSCIOUS PROCESSES

Chapter III

PERCEPTION

Look at figure 2 on opposite page. What do you see? At first glance most individuals report that it is a picture of a pair of stairs. Now look at the picture again and see if you are able to see this figure as a picture of something else? Can you see it as a stairs from underneath or as an overhanging cornice? If you have difficulty in seeing it this way, look intently at some point on the line marked *BD*. Then you will find that the triangular space above will appear to be nearer to you than the similar triangular space below and you will seem to be looking up underneath the stairs. But you can see this figure in still other ways. Look intently at the middle of the line marked *AB* and it will seem like a folded or plaited piece of paper lying on top of a background and the two triangular surfaces above and below will seem to be in the same plane. Now look at the figure again but this time looking at the center of the line marked *CD*. Now it will seem as if that edge of the plait will be toward you. Then look back intently at the middle of the line *AB*. It is the same plaited paper but with plaits in the opposite direction.

Indeed you should certainly be able to see this figure in at least four ways: as a stairs from above; as a stairs from beneath and the two ways as a folded piece of paper. The figure presented on the page has been the *stimulus* and what you have seen are called *perceptions*. Sometimes they are called *sense perceptions* because they are the result of the stimulation of a sense organ which, in this case, is the eye. In the present case certainly the stimulus has not changed but you have been able to obtain, one after the other, four different perceptions from the same identical stimulus. As a matter of fact, none of your perceptions actually correspond to the stimulus figure. All of your perceptions seemed to be three-dimensional—the staircase or the overhanging cornice seemed to have one side nearer to you that the other. But the figure is actually only two-dimensional—flat black lines on a white printed page. It is possible to see this as a flat two-dimensional figure, but I think that you will find more difficulty in this than in any one of the other four perceptions of three dimensions. Perceptions like this which do not correspond to the stimulus have been called *illusions.*

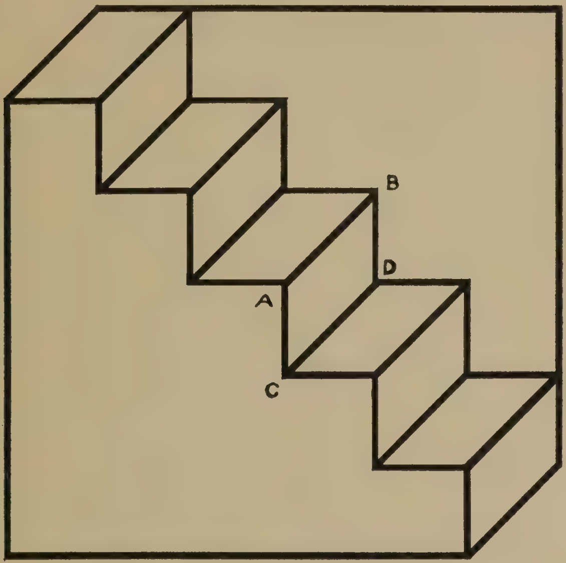

Fig. 2

This demonstration has been given here to indicate that perceptions are clearly complex. One usually thinks of seeing or hearing or touching as simple while it turns out that they are not only complex, but as we shall see, even much more complex than we now suspect.

For example, I raise the question as to why you first saw this figure as a staircase rather than as a cornice or a folded strip of paper. The answer is simple—you have had more experience in the past with stairs than with the other objects. This situation may be expressed in terms of a formula which would read: *Perception* = *sensation* + *apperception.* In this case, perception is what you see—the staircase or the cornice—and to express the complexity of this conscious experience, the rest of the formula says that there is an effect of the stimulus on the sense organ (sensation) plus some contribution of past experience (apperception).

Let us suppose that three men were standing on a hill looking over a plain below. One is a soldier, one an architect and the third an artist. Each would see something different in the view before him. The soldier would see the plain from the military point of view and would consider where he would dig his trenches and where he would place his guns. The architect might consider where he would build a house and what kind of a house he would build and how he would lay out gardens around it. The artist would see the scene from the point of view of a possible painting—the grouping of the colors and of the lights and shades. The artist might particularly notice a sunset which the other two had missed. The soldier might be the only one to perceive a slight gulley which would give shelter from enemy fire; while the architect might perceive a slight rise in ground as the location for his house. Each of the three have a different background of experience—a different apperceptive background—and this leads each to see—to perceive—something quite different in the same physical stimulus.

We shall find that the situation is much more complex than this and we already know, from our own experience with the staircase figure, that the point at which you look most intently

—which you fixate—has an effect on what you will see. This can be demonstrated more clearly by figure 3. If you will look at this figure for a minute you will discover that sometimes the facets are toward you, apparently above the surface of the paper, and sometimes they are away from you,—they seem to recede into the page. If you want the facets to appear toward you, you must carefully fixate the center of the horizontal line of the figure. If you want the facets to recede, you must fixate the outside edge of the figure. But in the seeing of this figure the slanting lines tend to make it difficult to hold your glance in any one place. Your eyes tend to move from one place of fixation to another and so the figures seem to recede and come out from the page.

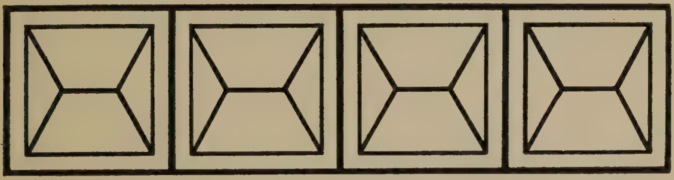

FIG. 3

What you *expect to see* also may determine what you will see in a figure. This has been called *preperception,* because it is a preparation by your past experience before the stimulation and before the conscious perception. I am sure that if you look at a slide through a microscope for the first time you might see many things, but if this slide were shown you again at the end of a laboratory course in biology, you would actually see more than you had the first time. You would see more because your course in biology would have given you a group of preperceptions and you would see more because you would know ahead of time what sort of things you might expect to see.

Some psychologists have emphasized the fact that perception is complex while others have gone still further and insisted that sensation—the direct and immediate result in consciousness of the stimulation of a sense organ—is simple and they have further insisted that sensation is truly the mental element. By this they mean that sensation cannot be further analyzed into simpler parts in the way that we were able to demonstrate that perception could be broken up. All of this reasoning may be correct, but it is truly a purely academic question which has really no place in experience. It may well be that sensation is a mental element, but certainly, because of the contribution of past experience, we never are aware of a sensation in its pure form and in isolation. Other psychologists have taken an exactly opposite view and have said that perceptions are configurations and that they cannot be fruitfully analyzed. When you look at a chair you see a chair and not a combination of the seat, the four legs and the back. It is not possible to analyze a musical melody into the individual notes of which it is composed without destroying the melody. Consider figures 4 and 5. You will report at once that the lines *A* and *B* fall into one pair and the lines *C* and *D* fall into another pair.

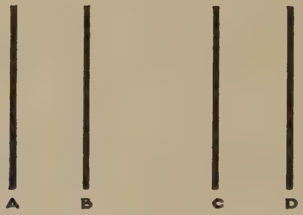

FIG. 4

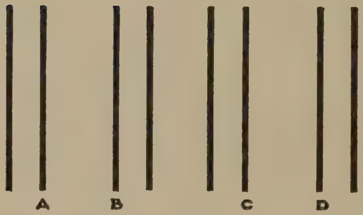

FIG. 5

Let us add four more lines as in figure 5. The spatial relations of the lines *A*, *B*, *C*, and *D* are exactly the same as they were before but the addition of the new lines cause the former pairs to fall apart and to appear as members of different pairs.

But certainly we can say that some perceptions are relatively simple while others are relatively complex. The back cover of this book represents a rather simple perceptual situation. It is a patch of plain color with a definite shape and it is certainly much simpler than the perception of a phrase of the text on this page. It is true that as you read you perceive each word or phrase as a unitary experience—each word is not read as a combination of letters composing it. Indeed, the word constituton will be read quite readily as constitution and psychology, with only the upper halves of the letters showing, will be read as psychology.

In the succeeding chapters, we shall treat the different kinds or *modalities* of sensory perception both simple and complex. We shall talk of simple color and pure tone, on the one hand, and of complicated visual and auditory perceptions on the other, ignoring the question of whether one kind of experience has to do with mental elements and the others not. We shall therefore use the terms sensory and perceptual interchangeably as indeed they are in actual uncritical experience.

The man on the street, following Aristotle as we have seen in the last chapter, believes that there are five sensory modalities—seeing, hearing, tasting, smelling, and touch. Actually we shall find that this list is most inadequate. Touching is exceedingly complex and includes at least four or five modalities or kinds of sensory experience. And there are a number of sensory modalities not included in Aristotle's list at all and all of these are exceedingly important for human personality.

In treating each of these modalities we shall be interested in the *stimulus*, in the *sense organ*, in the number of totally different qualities or experiences and in the number of experiences which may be distinguished from one another. The study of the stimulus—which is really physics—and that of the sense organ—which is really physiology—will be made as brief as possible. But they add greatly to an understanding of the psychological processes which result when the stimulus affects the sense organ.

A great deal happens between the stimulation of the sense organ and the conscious psychological process. In the first place, the physical energy represented by the stimulus is changed, in the sense organ, into another form of energy called *nervous excitation* and this travels along the nerves from the sense organ to the brain. When this nervous energy reaches certain parts of the surface of the brain, then and only then, do we have the conscious experience. It now seems clear that this nervous energy is a form of electrical-chemical energy. It takes a definite and easily measurable time for this transformation to occur. We can easily measure the time between a stimulus affecting the sense organ and the resultant consciousness. We shall find that the form of the anatomy of the sense organs, and this is especially true in vision, actually determines what kind of conscious experience we shall have. We shall seek all of the aid that physics and physiology can give in solving our psychological problems.

Two of our strictly psychological problems in the study of perception have to do with the number of *totally different* and the number of perceptibly or *discriminably different* experiences. Both involve psychological measurement of the forms devised by Fechner mentioned in the last chapter. As has already been said, Fechner devised a number of such *psychophysical measurement methods* and others have been added since his time and improvements have been made in them by a number of other psychologists. They are too complicated and too highly technical to be discussed in the present volume.

The important fact about all of the psychophysical methods is that they determine what has been called a *threshold* or *limen*. If we start with a given tone and gradually increase the pitch very slowly and by very small steps, we eventually come to a tone which is perceived as different from the first with which we started. But if we repeat this procedure a second time we will not necessarily report the difference at exactly the same interval. At one time we may report the difference sooner and at another time we may need to more widely separate our first and second tones. Similarly if we lift first one weight and then another weight which is only slightly different we may sometimes report the second weight as lighter; sometimes as heavier and sometimes as actually equal to the first weight. As you proceed slowly and with very small differences up or down a stimulus scale, one does not suddenly experience all at one level one kind of experience and then suddenly and invariably, when a given point is reached, always report another and different kind of experience.

This variability of judgment when differences between two stimuli are small has been recognized and has lead to a statistical definition of the threshold. The threshold is defined as that value of stimulus which will arouse a particular kind of conscious experience usually in 50 per cent of the cases while in the other 50 per cent of the observations, the same stimulus will arouse either no conscious experience at all or some other kind of conscious experience. In other words, a threshold is that value of stimulus which is just as likely to arouse a certain kind of conscious experience as not. Thresholds are of three sorts. There is the *stimulus threshold* at the lower end of the stimulus scale, which is the value of stimulus just large or strong enough to arouse a conscious experience at all in 50 per cent of the observations. Another is the *difference threshold* which is the difference between two stimuli which will arouse a perception of difference between two conscious experiences in 50 per cent of the trials. And thirdly, there is the *terminal threshold* which, for some modalities of sensation, measures the upper limit of conscious experience in 50 per cent of the trials.

With these definitions of threshold in mind, we shall now turn to a discussion of the different modalities of sensory and perceptual experience.

QUESTIONS

1. What is the difference between sensation and perception?
2. How does previous experience influence present experience?
3. Why is perception regarded as a complex mental process?
4. What neurological processes do all perceptions have in common?
5. What is a limen or threshold?

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CHAPTER IV

VISION—WITH THE SINGLE EYE

It seems better to present the facts of vision in two chapters; in the first will be treated the simpler processes which may be treated as those dependent only on the use of one eye (*monocular vision*) and, in the second chapter, those facts of vision requiring the coöperation of both eyes (*binocular vision*).

The *stimulus* for vision is light, which has been described as *radiant energy*. This consists of very rapid vibrations in that hypothetical medium which is said to fill all space and which the physicists call ether. By no means do all vibrations in the ether effect the eye and evoke visual experience. Only those vibrations between the range of approximately 435 million million per second and 770 million million per second are effective. The slower of these arouses sensations at the red end of the spectrum and the faster arouse experiences at the violet end of the spectrum. Those vibration frequencies between the two extremes are the basis for the various other colors of the spectrum.

Just below this range of vibration frequencies in the ether are the infra-red vibrations and just above are the ultra-violet vibrations. Besides these are the etheric vibration frequencies for radio, for the x-ray, the actinic or chemical rays from the sun and many other kinds besides. The human organism has no sense organs which are directly sensitive to any except those within the range of visual sensation.

The sense organ for vision is the eye, whose gross anatomy is to be found in figure 6 in which the facts are presented only in schematic fashion. It will be seen that most of the eye is either a containing box or a focusing mechanism—only a very small part is the sensitive visual end organ. The arrangement of the parts of the eye makes it very much like a camera, and in the figure, there have been drawn schematically an eye and a camera side by side. The eye ball is nearly spherical with a bulge at the front end. In back of this bulge is the *iris*—that part which gives the color to the eye: blue, brown or hazel. The function of the iris is to allow more or less light to enter the eye. It contains two sets of muscles with a hole in the center called the *pupil*, through which the light enters. If the amount of light is increased, the hole becomes smaller—the pupil contracts. If the amount of light is decreased, the hole becomes larger—the pupil is said to dilate. You can demonstrate this action of the pupil for yourself by standing in front of a mirror in a light room. Cover your eyes with your hand for a minute completely shutting out the light. Then remove your hands and quickly look into the mirror at your own eyes. You will see that the pupil is quite large at the moment when you remove your hands and that it quickly contracts in the presence of the increased light. This action is so entirely automatic that most persons are not aware of this action until

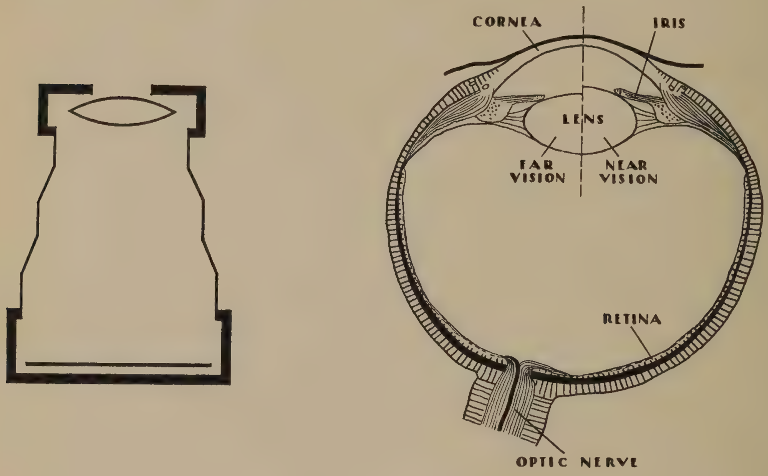

FIG. 6

their attention is called to it. The function of the iris is exactly the same as that of the diaphragm of a camera. Both control the amount of light which is allowed to fall upon the sensitive mechanism.

In back of the iris in the eye and the diaphragm in the camera is found the *lens*. The function is the same in both cases, namely, to focus the rays of light on the sensitive surface. In the case of the camera, the shape of the lens remains fixed and the focusing is accomplished by changing the distance from the sensitive plate or film in order to produce a sharp and clear image. In the case of the eye, the position of the lens remains fixed and the focusing is accomplished by a change in the shape of the lens itself. For objects near to the eye, the lens becomes more rounded and for objects far from the eye, the lens becomes less rounded in order to accomplish this clear focusing. This change in the shape of the lens is accomplished by the degree of pull or tension on the lens by sets of muscles at its edge and is also entirely automatic as it was in the case of the iris. We shall have more to say about these automatic adjustments of iris and lens in a later place.

At the rear of both the eye and the camera is found the mechanism or structure sensitive to light, which is affected by the light falling upon it. This is the film or plate in the camera and the *retina* in the eye. If one looks at the retina through a strong microscope it proves to have a very complex arrangement of nerve cells. Due to the differences in the shapes of the two instruments the plate in the camera is flat while the retina is curved and extends over the entire inside of the back and sides of the eye. It will be noticed that the optic nerve, which is a collection of nerve fibers extending from the retina to the brain and which transmits optic nerve energy, is found to the side (the nose side) and not centered at the back of the eye.

Directly at the back of the retina, in the path of the direct line of sight, there is a slight depression in the retina which is called the *fovea*. The arrangement of the nerve cells in the fovea proves to be somewhat different from that found elsewhere in the retina. This area, the fovea, is much more sensitive to light than other parts of the retina and there is a marked decrease in sensitiveness as light moves from the fovea toward the edge or *periphery* of the retina. The outside layers—the white of the eye—consists of a fibrous tissue which corresponds to the light proof box of the camera.

No one knows exactly what happens in the retina when light falls upon it. Certainly the light stimulus sets up some sort of a photochemical reaction in the nerve tissue and thus the transformation is made from the radiant energy of the stimulus into nerve energy. There are a number of theories as to what happens to account for this transformation of energy but the evidence is so far from definitive, at present, that it seems a waste of time to present any one of these theories even briefly.

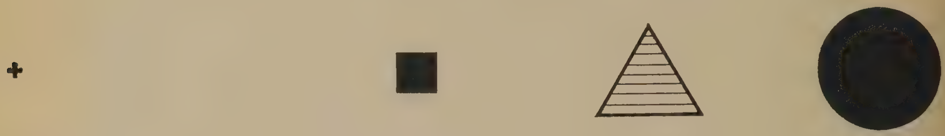

Fig. 7

At the point where the optic nerve leaves the sphere of the eyeball, there are no cells sensitive to light. This part of the retina is called the *blind spot*. Its existence can be demonstrated with figure 7. Turn the book horizontally. Cover the left eye with one hand. Hold the cross directly in front of the right eye. Then holding the chart exactly horizontally move it backward and forward slowly, and in succession, each of the other figures will disappear as it falls within the area of the blind spot.

Ordinarily we are not aware of the existence of such a blind spot. Our visual field seems to be entirely continuous and there does not appear to be such a break in the continuity of visual space. This situation presents an exceedingly interesting psychological fact, because in our normal mental life, the area of the blind spot is filled out by the context of the surrounding objects. You can convince yourself of this by looking at figure 8. As before hold the left eye closed and hold the chart exactly horizontally with the cross in the direct line of vision so that it falls on the fovea. Then move the chart back and forth until the center of the figure disappears. At this point the solid black circle will disappear and the figure will look like two interlocked continuous circles. This is another example of how much influence the apperceptive background of past experience plays in our visual perceptions.

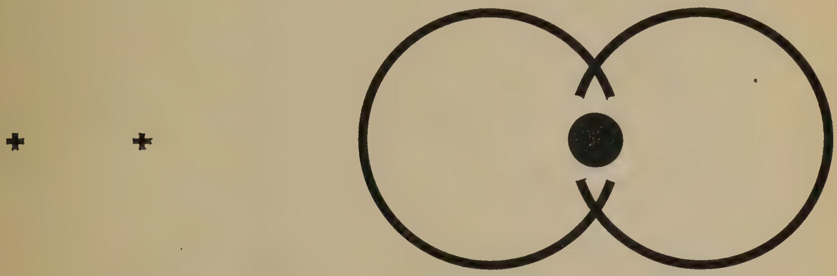

FIG. 8

Still another example of the importance of our apperceptive background is to be seen in the facts dependent upon the physics of the lens of the eye. This is a double convex lens—it bulges outward in front and back, and as is true in all such lenses, the image is completely inverted as it is by a similar lens on the ground glass of a camera. This can readily be seen in figure 9. An even more striking demonstration of the inversion of the image on the retina may be made with as simple apparatus as a pin and piece of cardboard. This experiment is pictured schematically in figure 10. Make a small pin hole in the card and hold it very close to and directly in front of one eye, closing the other eye. With the other hand, place the pin between the cardboard and the eye in such a way that it can be seen. The pin hole, being small allows practically only parallel rays of light to pass through. Thus the pin casts a shadow into the eye. The rays of light are deflected by the shape of the lens but the shadow—which is not composed of rays of light—are not so deflected. Hence the pin will appear to be upside down and visually it will appear to move in the opposite direction from that in which you may move it.

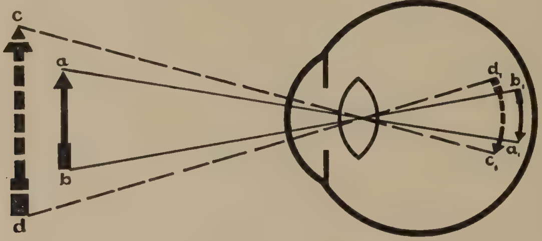

FIG. 9

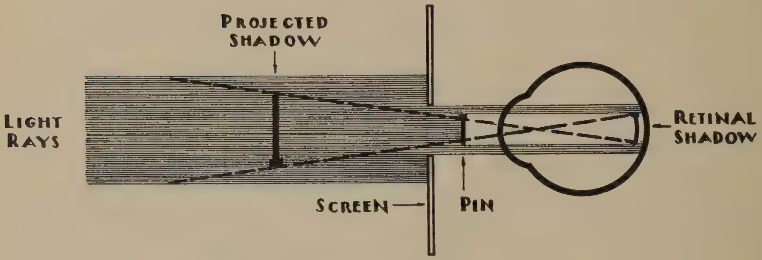

FIG. 10

To illustrate this point of the inversion of the retinal image and its psychological correction by past experience so that we actually see objects right side up, the following experiment was performed a number of years ago. During all of his waking hours, the experimenter wore a pair of glasses the lenses of which inverted the image so that with the reinversion due to the lens of the eye, the image on the retina was actually right side up. With his apperceptive background of normal correction, this investigator started to live in a world which appeared to be upside down. Within a few weeks he had built up a new apperceptive background to this new situation and his world righted itself for him. But now the trouble came when he took off his glasses and wanted to stop the experiment. Having built up the new correction from his several weeks of past experience, when he removed the glasses so that there was only the normal single inversion of the retinal image, he again found himself living in an upside down world and again had to build up his former psychological correction of past experience before the world in which he lived became right side up again.

So much for the discussion of the mechanics of the single eye. Now we must consider the simplest kinds of visual experience and we are at once faced with the problem of the number of totally different visual experiences. If you remember the small paint box your answer to this problem would probably be that there are three primary or totally different colors—red, yellow and blue. If you have a background of physics you would probably also answer three because physics teaches that all of the colors may be made up by mixing not more than three properly chosen colors. Some of you might answer that there are seven totally different colors thinking of the spectrum with its red, orange, yellow, green, blue, indigo and violet.

Some of these seven spectral colors are certainly not primary or totally different colors. If you had never seen orange but knew red and yellow, you could certainly describe the new color as a reddish yellow or a yellowish red. It would be introspectively possible to analyze the complex orange into its two components—red and yellow. Similarly indigo and violet turn out to be compound colors with several components.

On the other hand, everyone would agree that red, yellow and blue are psychologically simple and are totally different conscious experiences. What then about green on which opinion seems most to differ? The artist will say that green is certainly not a fundamental color. He will say that he can obtain it by mixing yellow and blue out of his paint box. But the psychologist, and gradually more and more artists, recognize green as a primary totally different conscious experience which is not analyzable into blue and yellow *introspectively* in the way that violet may be analyzed into its constituents blue and red.

And what about white and black? The physicist will tell you that both are a mixture of all of the wave lengths of visually sensitive radiant energy; that they are a combination of all of the spectral colors. They will say that white is this very complex mixture at high intensities and that black is the same mixture at low intensities. There is no question about the truth of these facts from the physical point of view. If white light is passed through a prism it will be broken up into the entire spectrum.

Look now at the white paper at the edge of this page and then at the black print. Certainly you are not able to see red, orange, yellow or any of the other spectral colors in either the white or black. We can only come to the conclusion that psychologically white and black are simple unanalyzable totally different conscious experiences. Thus we must finally conclude that there are six totally different visual experiences: the chromatic or colorful including red, yellow, green and blue; and the achromatic or colorless including white and black.

All other visual experiences are complex and consist of mixtures of two or more of these simple experiences. Thus orange is a mixture of red and yellow; violet is a mixture of red and blue; brown a mixture of red, yellow and black and so on.

If we mix colors either by mixing colored lights or by rapidly rotating colored discs before the eye, we find it possible to produce all possible colors if we choose the correct combinations of our six primary visual experiences and if we mix them in the proper proportions. There are only two laws of color mixture which need to be presented at this time. The first says that for every color there can be found another, complementary or antagonistic, which if mixed with it in the proper proportion gives a colorless gray. It will be found that our six fundamental visual experiences fall into three complementary pairs. Obviously when white and black are mixed together they give a colorless gray. But also a colorless gray may be obtained by the proper mixture of yellow and blue, and if you choose the proper colors to start with, of red and green. Hence we must think of our six visual experiences as three complementary pairs: red-green; yellow-blue and white-black. We shall find these complementary relationships important in all of the simpler visual experiences.

The second law of color mixture says that the mixture of any two colors which are not complementary gives an intermediate color. Hence, as has already been said, the mixture of red and yellow gives the intermediate orange. In this way we may experimentally discover the number of discriminably or perceptibly different visual experiences. It has been found that there are approximately 180 such different chromatic experiences in the spectrum from red to violet and approximately 660 such achromatic experiences from white to black. When all possible combinations are made, it has been estimated that there are approximately 40,000 perceptibly different visual experiences at this simple level.

Each of these experiences may vary in any of three ways. The first of these is quality—that attribute of experience which is the basis of the color name: blue, violet or orange. The second is brightness or intensity such as a light tint as against a dark shade. And the third is saturation which is the amount of color in a visual experience. It has been found that the spectral colors have the greatest degree of saturation; all others seem more washed out than these. One can illustrate saturation in the following way. Take a bottle of red ink which is only one-fourth full. Add clear water until the bottle is half full. You will find that it is the same red as before—there has been no change in quality—but you will also find that it is less red than it was before—the new mixture has less saturation.

Add still more clear water to the mixture and you will again decrease the saturation without effecting the quality of the mixture. These relationships among visual experiences have

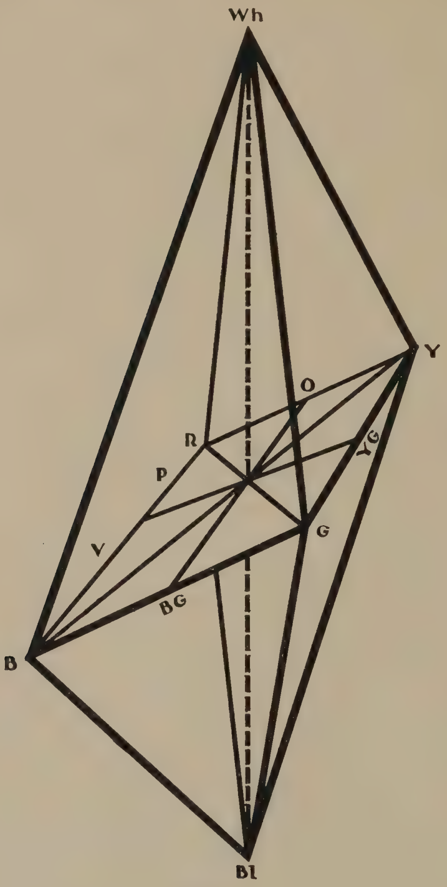

FIG. 11

been systematized and classified in figure 11. This figure takes the form of a double pyramid with the bases superimposed. In this figure the four primary colors: red, yellow, green and blue are placed at the angles of the bases. The colors of the entire spectrum are found around the circumference of this quadrilateral. For example the spectral purples and violets are on the line between blue and red. The dotted line, marked *Wh–Bk*, indicates the series of pure grays—the achromatic series—with the totally different experiences of white and black at the extreme ends. Complementary colors are those at the ends of any line drawn as a diagnonal through the grays. Such lines have been indicated on the figure for yellow and blue as simple complementaries, and also to indicate that the complementary color for the complex yellow-green lies somewhere between purple and violet. In this figure all of the tints are found in the upper pyramid because each of these colors has an admixture of white. Similarly all of the shades are in the lower pyramid because each of these colors has an admixture of black. One must conceive this as a solid figure and not one in which the possible colors are merely arranged on the surface. If one should peel the figure as you peel an onion, one would find exactly the same colors upon the new inner surface as had been upon the outer but with less saturation because this entire surface is closer to the central achromatic line of the colorless grays from black to white.

Whatever may be the physiological basis in the retina for the several totally different visual experiences (and we have not presented any of the theories because none of them seem to have enough evidence to be substantiated) there is, nevertheless, plenty of evidence which indicates that the sensitivity to various colors is not evenly distributed over the entire retina. This becomes plain when one determines the so-called color fields of the retina which are illustrated in figure 12. One then finds that the entire retina is sensitive to both black and white. A somewhat smaller area is also sensitive to both blue and yellow and a still smaller area about the fovea is also sensitive to both red and green. Thus it can be seen in the figure that the central area about the fovea is sensitive to the stimuli for all six kinds of visual experiences. The surrounding area is sensitive only to white, black, blue and yellow. The outermost or peripheral area is sensitive only to white and black. If a primary color—such as red—is brought from the periphery of the retina toward the fovea, it will be seen at the edge as gray only—the brightness factor alone will be perceived—and it will continue to be seen only as gray until it reaches the edge of the red-green field. Then it will be perceived as red and the quality will remain unchanged from there to the fovea.

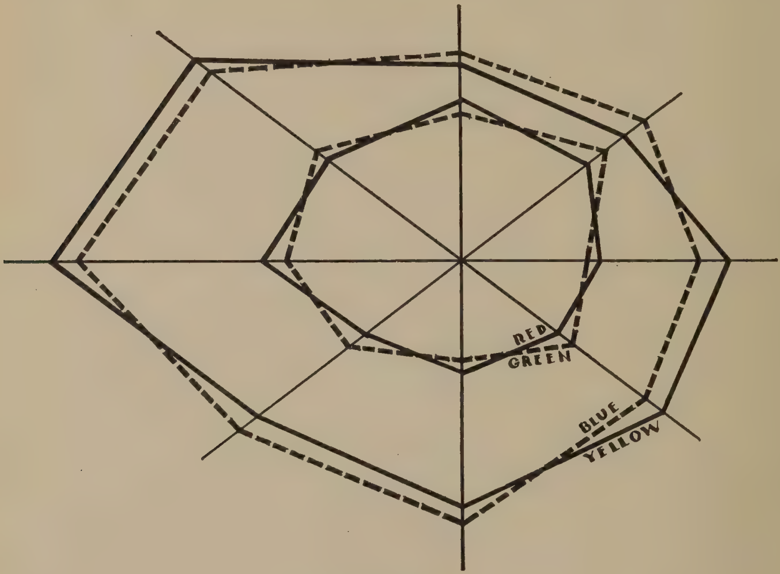

Fig. 12

If a complex color, such as orange, is moved from the periphery toward the fovea, it will first be seen as gray. Then when it reaches the edge of the yellow-blue field, the yellow component will become effective and it will be perceived as yellow without change as it crosses this field in the retina. Only when it reaches the edge of the red-green field will the red component become effective and then it will be seen as orange. All of these facts emphasize the relationships of the six fundamental visual experiences, which must be considered as three complementary pairs.

Additional emphasis is given to these same facts by the phenomena of *color contrast.* If you should place a small piece of red paper on a gray background and look at it without eye movement, you will discover that the stimulus is surrounded by a halo of the complementary green. This is true of any visual quality and it is a useful way of determining which is the complementary to any color. An impressive demonstration of color contrast is outlined in figure 13 in which the ground plan is given. In the center of a board erect a pencil or some similar object (*C*) and at two corners place candles (*A* and *B*). When the room is darkened, two shadows will be thrown by the pencil: shadow *A* from candle *A* and shadow *B* from candle *B*. Each of these shadows will be a dark uncolored gray. Now place a piece of colored glass in front of candle *B*. Obviously all of the field will be colored by the light from this candle going through this colored glass except the shadow *B*.

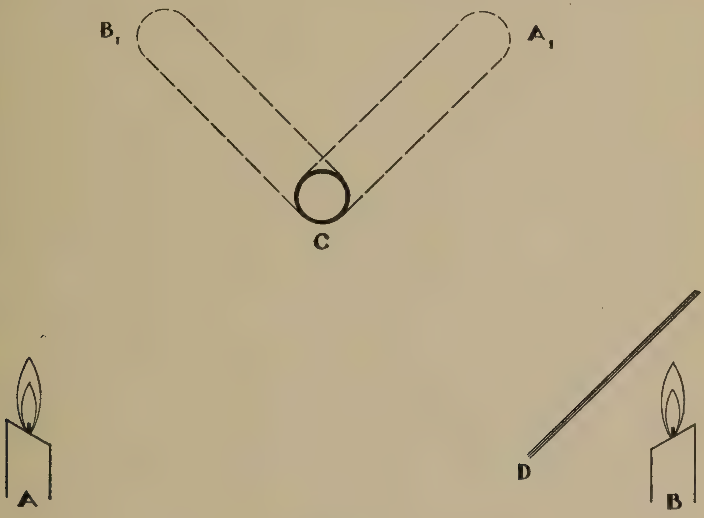

FIG. 13

This shadow will physically still be the same gray, of course, because it is still illuminated only by the light from candle *A*. But the shadow *B* will now appear rather brilliantly as the complementary of the color of the glass because of visual contrast.

Some years ago, the author was called as an expert witness in a case involving color contrast. A cloth weaving mill received an order to produce some cloth for women's suitings for which the client specified a small check with a certain specified green and a certain specified gray. The cloth was woven exactly according to specifications—alternate squares of the specified green and gray threads. However, when the cloth was woven it appeared as a very unaesthetic check of green and light red. The checks were of such a size and the green and gray of such a quality to enhance the factor of visual contrast so that the physically gray squares were perceived as the red complementary of the neighboring green squares.

The facts of colorblindness again emphasize the complementary pairedness of the six primary visual experiences. Except for a very few cases in the literature of this topic, all individuals who were unable to perceive red are also colorblind to green as well, while those colorblind to yellow are also unable to perceive blue. In those cases of colorblindness where a certain pair of colors cannot be seen, stimulation by the frequencies corresponding to this color arouses a gray. It was formerly believed that colorblindness was an "all or none" proposition—an individual was either colorblind or he was not. More recent research indicates that this is not true. It is possible to arrange a group of subjects in an unbroken series from total colorblindness at one end, through various degrees of color weakness, through normal color vision, up to highly superior color vision at the other end. There are very few totally colorblind individuals—ones who cannot perceive red, green, yellow or blue or any combinations of these but who must see the visual world only as a series of different grays.

On the other hand there are a very great many persons so color-weak to red and green as to be practically color blind to these two colors. Tests for railway engineers, for officers of ships and the like, where a distinction between red and green is highly important, indicate that approximately 4 per cent of the male population have insufficient red-green vision to enable them to make the necessary accurate judgments of these lights for these professions.

It is interesting, and perhaps unfortunate, that red and green should have been chosen as the colors for traffic lights inasmuch as these two colors are the most susceptible to color weakness and color blindness. It is fortunate that the particular red and the particular green which have been chosen happen to have great brightness differences so that the color blind individual may differentiate the two on a brightness basis although he is unable to actually distinguish them as colors.

We have used the masculine pronoun throughout the discussion of color blindness on purpose. Results show that the percentage of color blind in the male population is exceedingly greater than among females. Indeed it is only rarely that one encounters a color blind woman. This is because for color blindness there is a certain kind of inheritance which makes it of great interest to students of genetics. Color blindness is inherited by the male through a mother who is not herself color blind but who is the daughter of a color blind father. Thus, if a man who is color blind should have a son and a daughter, neither might be color blind and the daughter almost surely will not be. The son might produce children of both sexes none of whom are apt to be color blind. But the daughter is apt to have color blind sons and daughters with normal vision for color.

Still another factor in simple vision depends on the sort of light stimulus to which the eye has previously been exposed before any particular stimulation. If you should pass from bright sunlight into a fairly dark room you would, at first, be able to see little if anything. As you stay in the darkened room you will be gradually able to see more and more until in time all of the objects will be distinguishable. You will have entered the room with the eyes in a condition of light adaptation and, due to the poor illumination in the room, the eyes have become changed to a condition of dark adaptation with the result that you have acquired greater sensitivity to this new illumination. The same sort of decrease in sensitiveness occurs if you start with the eyes in a condition of dark adaptation by being for some time in a dark room and then stimulate the eye with bright light. The speeds of these two sorts of adaptation are very different. Light adaptation is much more rapid and is practically complete in some three minutes while dark adaptation is not complete until the eye has been unstimulated for approximately a half hour.

It has been found that there may also be adaptation to a particular color as the result of continued stimulation. If you should put on a pair of green glasses and look at a white card, it will at first appear green, but if you continue only to allow green light into the eye for a half hour, the card will appear by that time as a colorless gray. All of this indicates that what you see is not only dependent on the quality and the intensity of the stimulus but that it is also dependent in part on the photochemical state of the retina at the time of stimulation. It is possible to fatigue the retina to any color so that stimulation by that color becomes less effective.

One effect of light and dark adaptation is an interesting shift in the more effective colors under the two conditions. This has been described as twilight vision. In light adaptation the yellows and greens are most effective: in dark adaptation the blues and the violets are the more effective colors. This becomes apparent if you continue to view a landscape after sunset as it is gradually growing dark. In this situation you are slowing passing from a condition of light adaptation to one of dark adaptation. Thus as the condition of the retina shifts from light to dark adaptation, you will notice that the effectiveness of the colors change very considerably. You will notice that the reds drop out first, then the yellows and greens until only the blues and the violets remain effective.

We have spoken of adaptation to color as being a phenomenon in the nature of fatigue. An interesting effect is discovered following such fatigue. This is the phenomenon of the visual after image. If you will stand before an electric light and turn it on and off rapidly while you are fixating the bulb and at once close your eyes, you will see an image of the light with the same brightness and color values. The filament will be the brightest part of this image, the outline of the bulb will be less bright and the background will appear darkest. This has been called the positive after image, one in which the after image has the same qualities as the stimulus. Positive after images are best obtained from short, intensive stimulation.

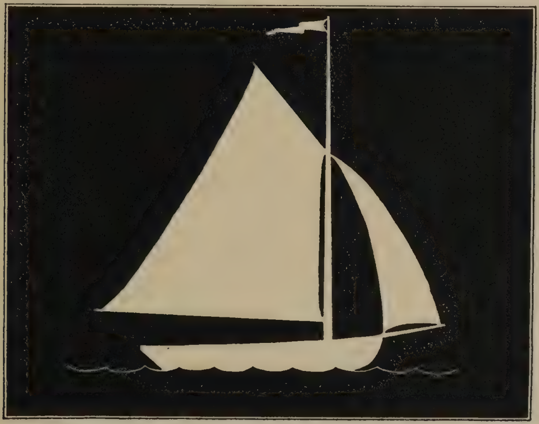

FIG. 14

There is also a negative after image in which the qualities of the after experience are the complementaries in both quality and intensity of the original stimulus. Look fixedly at the center of figure 14 for from 15 to 20 seconds avoiding all eye movement as much as possible. Then transfer your gaze to the center of a piece of blank white paper and you will see a figure which has the same form as the stimulus but with the brightness relations reversed. This negative after image may not appear *immediately* after you look at the blank white paper. There is frequently a period of latency between the end of the stimulation and the appearance of the after image. Similar after images may be obtained with colored stimuli. If you place a small half inch square of colored paper on a larger piece of gray paper and fixate it for some fifteen seconds and then blow away the small stimulus square, keeping the fixation constant on the gray background, you will discover a negative after image of a square of the same size of the stimulus but of a complementary color. Indeed one may produce color mixture in this way by substituting a colored background for the gray background and projecting the colored after image upon it. Hence, if you will fixate a yellow square of paper on a red background, when you blow the square away and fixate the red background alone the after image will appear either violet or purple. This violet or purple after image is produced by a mixture of the normal blue negative after image of the yellow stimulus and the red of the background. We shall have more to say about the after image in another place.

Throughout this discussion of the facts of vision with the single eye, we have emphasized the complementary relationships of the six primary visual experiences—white-black; red-green and yellow-blue. These paired relationships have been seen in all of the situations in which color has been discussed—in color mixing, color contrast, the color fields of the retina, color blindness and the negative after image.

QUESTIONS

1. Compare the eye and the camera as optical instruments.
2. What is the evidence for the existence of complementary colors?
3. What is the significance of the blind-spot?
    1. Physiologically
    2. Psychologically

4. How does apperception affect simple monocular visual experience?
5. Summarize the facts of
    1. After Images
    2. Color Fields
    3. Color Mixing
    4. Color Blindness
    5. Color Contrast
6. What is meant by light adaptation? Dark adaptation?
7. Distinguish between positive and negative after images.
8. Why is color blindness of interest to geneticists?

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Chapter V

VISION—THE COMPLEX PROCESSES

In the last chapter we have been concerned primarily with the simpler visual processes, which are those obtained with a single eye in a constant fixation. In this chapter, we shall treat the more complex visual processes obtained when the two eyes are used together, and when the fixation changes during the perception of a stimulus object. There are three major problems which must be considered in this connection: the visual perception of (1) shape (2) size and (3) distance from the observer. It will be discovered that the anatomical mechanism involved may be exceedingly complex for all three of these problems.

The anatomy of the single eye has already been explained briefly and simply in the last chapter. For these new problems it is necessary to consider the anatomical mechanism for binocular vision, that mechanism which not only makes the eyes move but makes them move in unison. Each eyeball is supplied with six muscles. The arrangement of these muscles may be seen from figures 15 and 16. At the top, bottom and each side of each eyeball are attached the so called *rectus* muscles. These work in pairs so that when one contracts the muscle opposite to it relaxes. If the muscle on the nose side of one eye contracts, the eyeball will turn inward. This arrangement is simple for the movements either sideways or straight ahead, but the situation is more complicated for movements upward and downward. This is because these four rectus muscles do not have their other attachment directly behind the eyeball. It will be observed from the charts that all of these muscles run toward the inner or nose side of the eye following the course of the optic nerve. This arrangement is

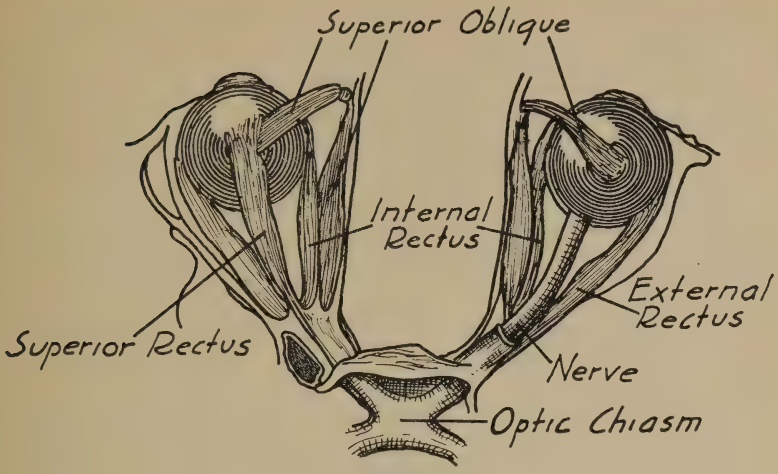

FIG. 15

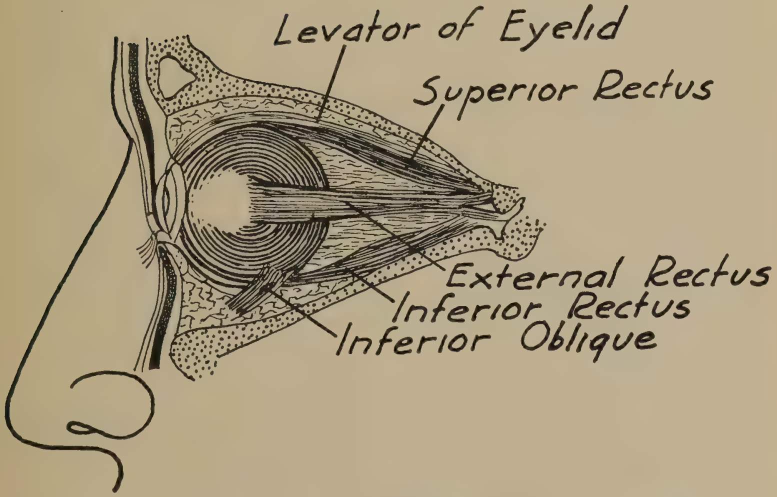

FIG. 16

necessary because, it will be remembered that the fovea, the point of clear vision, is directly at the back of the eyeball. Hence, if one of the upper or lower rectus muscles contracts, it will not only move the eyeball upward or downward, as the case may be, but will also *twist* the eyeball due to this out-of-line attachment. In order to overcome this tendency to twist the eyeball when it moves up or down, each eye is supplied with two other muscles called the *oblique* muscles. One is attached to the top and the other to the bottom of the eyeball, as can be seen in the figures 15 and 16. Each then passes through a loop on the nose side and then runs backward to its other attachment. If the upper oblique muscle contracts it tends to twist the top of the eye toward the nose and if the lower oblique muscle contracts, the top of the eye is twisted away from the nose. Hence an upward movement of the eye, without twisting, is accomplished by a contraction of the upper rectus and lower oblique muscles. A downward movement of the eye is accomplished by simultaneous contractions of the lower rectus and upper oblique muscles.

How important this muscular arrangement becomes may be determined by examining figure 17. Line *AB* seems certainly longer than line *CD*. With your finger cover the upper part of line *AB* until you judge it equal in length to line *CD*. On the average you will find that the vertical line must be shortened by at least 10 per cent before it seems equal to the horizontal line. Actually, of course, the two lines are exactly equal. This is called a visual illusion, and a number of other illusions of different kinds will be described in this chapter. The explanation of this vertical-horizontal illusion is really simple when thought of in terms of the arrangement of the muscles which move the eyes which has just been described. It will be remembered that the horizontal movements are accomplished in either direction by the contraction of a single muscle for each eye. The vertical movements require the contraction not only of two muscles in each eye (the rectus and its opposing oblique muscle) but these two muscles are actually working against each other. Thus the vertical line appears longer than the horizontal line because there is much more *muscular* effort required to make a vertical than a horizontal eye movement.

It can be clearly understood, then, that in binocular vision there is a great contribution from the muscles which control the eyeballs, a fact which is not usually understood but which cannot be overemphasized. Normal seeing with two eyes is therefore a complex of visual experiences from the retinas plus sensory experiences from the contracting muscles. In normal vision these contractions of muscle are automatic, like the reactions of the pupil and lens of the single eye already described in the last chapter. We shall have more to say about this type of movement in a later chapter which deals with reflex.

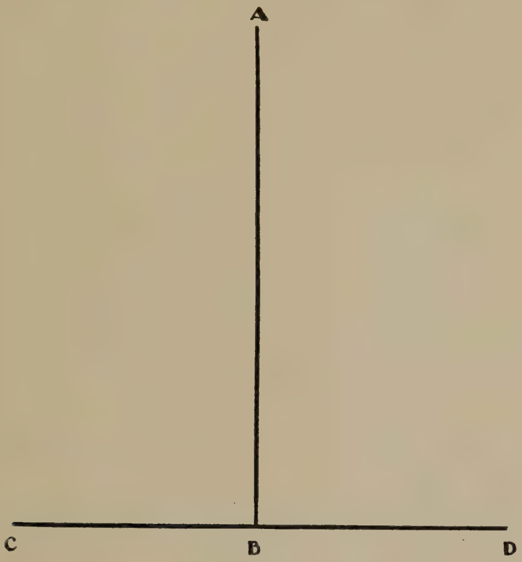

FIG. 17

Two important classes of eye movement are to be distinguished: (1) those of direction, or exploratory movements and (2) those of convergence. The so called *line of sight* is a line drawn through the center of the lens which falls in the center of the fovea. Figure 18, A and B, illustrates these two kinds of movement. In both cases the solid lines indicate the original position of the eyes, and the dotted lines, the position after the movement. Figure A illustrates exploratory movements or movements of direction. In this case the eyes move in unison as illustrated from a line of sight directly ahead to a new line of sight to the right. In Figure B, the eyes move in opposite directions. Starting with parallel lines of sight, the eyes converge toward the nose. Considerable convergence may be accomplished, but it is not possible in normal cases to obtain a degree of divergence greater than parallel lines of sight.

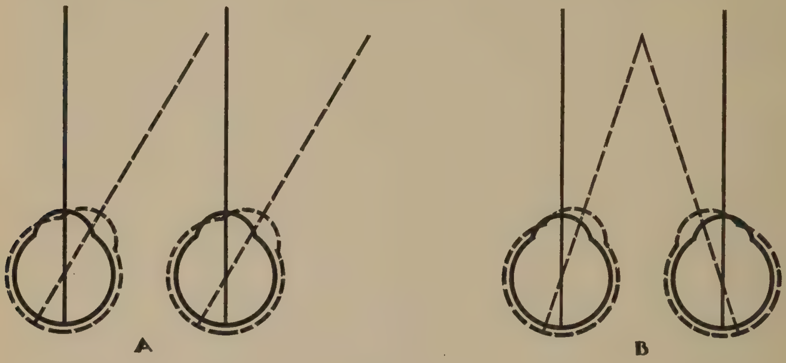

Fig. 18

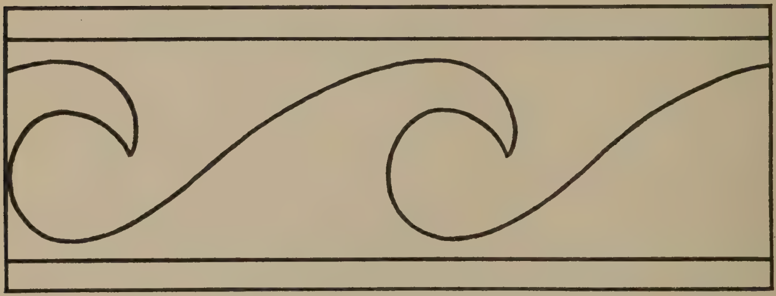

Fig. 19

It seems wise to consider first the movements of direction because they are the simpler. Look at figure 19. You will discover that you do not see it as a whole, but that your eyes move across it. Only seldom and with small objects which fall entirely within the fovea is a stimulus object seen without eye movement. For larger objects the eyes move in unison so that each part of the object successively falls on the fovea. Look at this figure again but this time notice where your glance first falls and in what direction the eye movement takes place. Almost universally the eye movement will be found to start at the left side and the lines of sight to proceed toward the right. Left to right movements seem easier than right to left ones while, as we have found, the up and down movements are still more difficult.

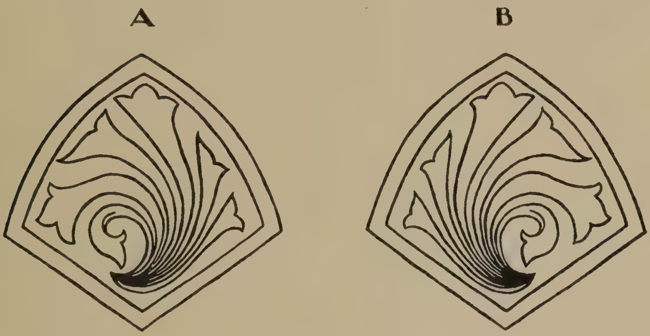

FIG. 20

The fact that left to right movements are the easiest seems to be the basis for most languages being written in this direction—Chinese and Hebrew being the notable exceptions. One might suspect that the movements are easier because of practice in reading in this direction, but there is experimental evidence that the left to right horizontal movements are also easier for those individuals trained to read in the different directions.

This fact that left to right movements are easier becomes important for certain problems of visual esthetics or in the appreciation of seen beauty. Look at figure 20. Which of the two figures seems the more beautiful? Which of the two figures do you prefer? Most individuals will say that they prefer A to B. Actually, of course, the two figures are exactly similar but placed in reverse directions. Analyze your eye movements when you look at these figures and you will discover that those for seeing A start at the left and follow the lines to the right and downward and finally come to rest on the point below which is well within the figure. The directional movements for seeing figure B, start at the same place on the left side and follow the lines upward and to the right and tend to stop entirely outside of the figure and thus the converged lines at the bottom may not be seen at all in clear vision.

The same principle becomes important in planning advertisements and especially so for street car advertisements which are frequently long and narrow in shape. In such advertisements something should appear on the left side of the advertisement to catch the attention, something should be in the center of the advertisement to guide the eye movements toward the right and there should be something on the right side to stop the eye movements. And this object on the right side of the advertisement is the important one from the advertiser's point of view, because this is the object which is the last seen and which, therefore, is most apt to be remembered. What that right hand object should be, should be determined by the advertiser's campaign of the moment. If he wishes to emphasize, at the moment, the package in which his product is sold, this should be placed to the right, but if his policy changes and he wishes to emphasize the name of his product, this should then be placed to the right.

In order to stress further the importance of directional eye movements in visual perception, several visual illusions are given in figure 21. Look at the heavy lines *AB* and *CD* in both figures A and B. In figure A the lines seem to bulge outward at the middle and in figure B they seem to bulge inward. Lines *AB* and *CD* are all actually straight and parallel. You can assure yourself of this by placing a ruler along any line. The apparent curvature of the black lines is caused by the radiating lines which intersect them. These intersecting radiating lines interrupt the eye movements along the dark parallel lines so that straight eye movement becomes impossible.

The same explanation accounts for the situation in figure 22 in which all of the heavy black lines are actually parallel. But the intervening crosslines throw out the eye movements so that direct and straight eye movement along any line or pair of lines becomes impossible.

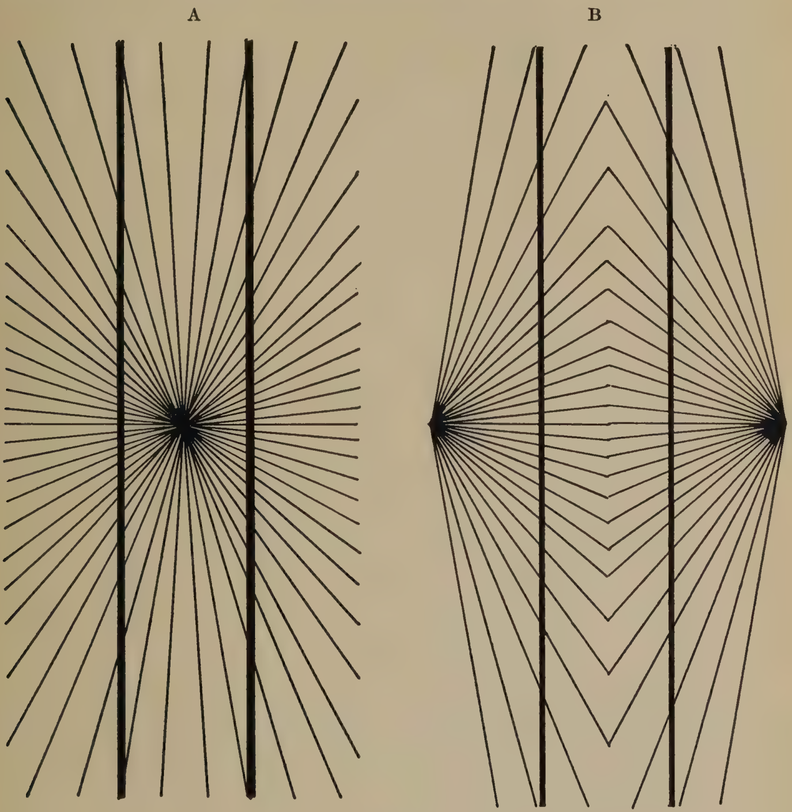

Fig. 21

The visual perception of the shape of an object is thus determined almost wholly, in normal vision, by the character of the eye movements necessary for the exploring of that stimulus object. It is true that shape may be determined, in some cases, without eye movement but this is true only in those cases in which the stimulus is so small that it falls entirely within the region of the fovea, and this turns out to be a rather unusual situation in normal vision.

The perception of the size of an object may be wholly a function of the size of the retinal image, but as with the visual perception of shape, this usually occurs in normal vision only in those cases in which the stimulus object is so small that it falls entirely within the foveal region. For most objects, the visual perception of size is largely determined by the *extent* of the exploratory or directional movements. If these directional movements of exploration are large, the stimulus object is judged to be large; if the movements are small, the object is judged to be small.

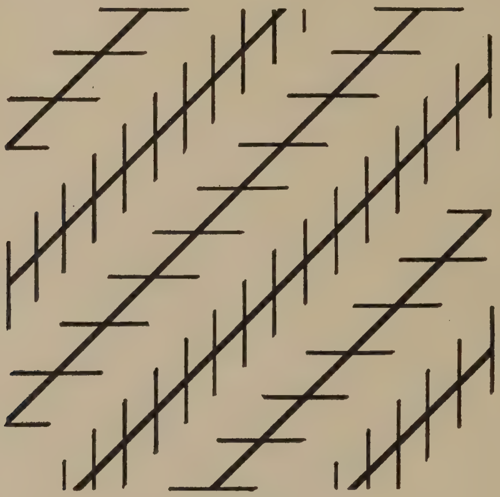

Fig. 22

The judgment of the size of an object, and particularly of a familiar object, is also determined to a certain extent by the distance of the stimulus from the observer. What cues give the basis for the judgment of distance will be treated later in this chapter. This factor of the consideration of distance in the judgment of the size of an object has, as its basis, largely one's apperceptive background of past experience. Hence an elephant at a distance would be judged larger than a dog close by, even though the retinal image of the dog was actually larger than the retinal image of the more distant elephant.

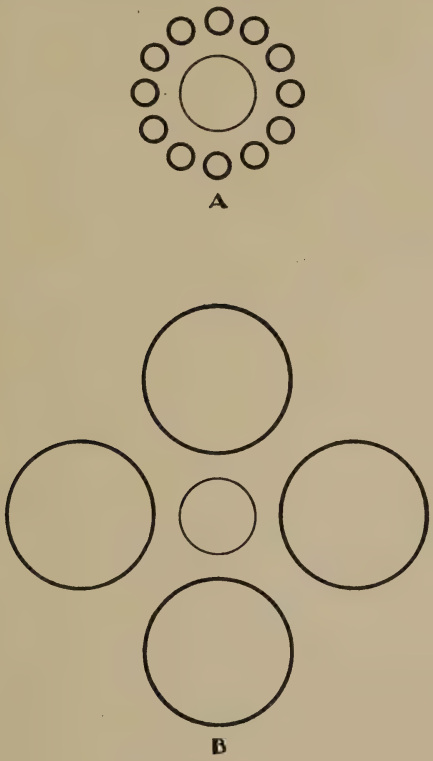

Fig. 23

The apparent size of an object is also partly determined by the objects surrounding it or seen at the same time. Look at figure 23. Which of the central circles is the larger? It will seem that the circle surrounded by the small circles would seem larger than that surrounded by the larger circles. Actually the two central circles have exactly the same diameter. But circle *A* is surrounded by small circles and seems larger and by contrast circle *B* is surrounded by large circles and seems smaller.

Any observer would declare, in figure 24, that circle *C* is largest, *B* intermediate and circle *A* smallest. This is because circle *A* is seen as part of a broad area only vaguely defined by the diverging lines and by contrast seems smaller, while circle *C* is called clearly to attention by the point within it and hence appears to be the largest. Actually, of course, all three circles have the same diameter.

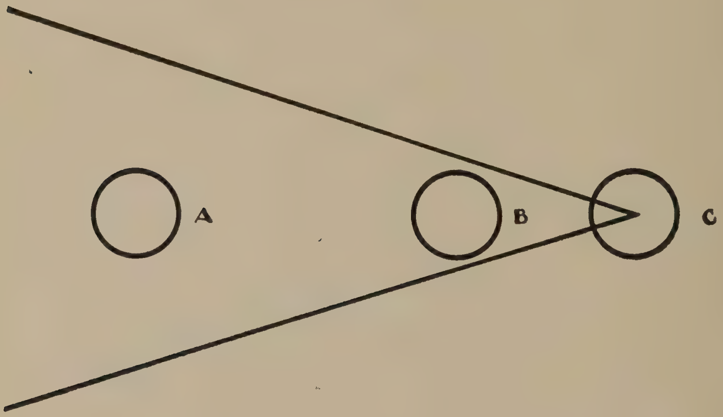

FIG. 24

In figure 25 compare the length of the line *AB* in figure A with the line *C′D′* in figure B. Which of these two lines seems the longer? Certainly the lower line in B seems considerably longer than the upper line in A. Actually both lines are the same size and you can convince yourself of this by actually measuring them. But once you have measured these two lines and convinced yourself that they are the same length, if you will look at the figure again you will find that the illusion of difference still persists. This illusion may be accounted for by the fact that when the eye moves across figure A it never travels completely across line *AB* because such an extent of eye movement is not necessary for the complete clear perception of the figure. But with figure B, the eye must move more than the distance *C′D′* for a clear perception of the entire figure. Because of these differences in the extent of eye movement the line *C′D′* in figure B seems longer than the line *AB* in figure A.

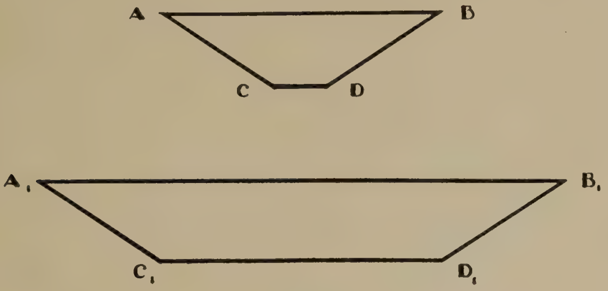

FIG. 25

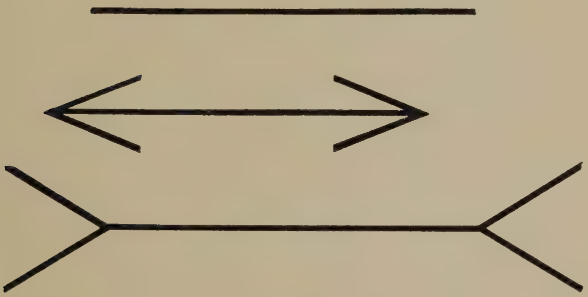

FIG. 26

Another similar illusion, dependent upon the extent of the eye movements is found in figure 26. The central line *AB* seems much longer than *A′B′*. They are actually equal. But to perceive clearly all of figure A, the eye must move very much more than is necessary to perceive all of figure B with equal clearness. Indeed to perceive clearly all of figure B, it is not necessary for the eye to move completely across the line *A′B′*. These differences in the extent of the necessary eye movements form the basis of the illusion.

Thus far in this chapter the emphasis has been upon the directional or exploratory types of eye movement which are necessary for the complete clear perception of any stimulus object so large that its image does not fall completely within the region of the fovea of the retina—the only place where clear vision obtains. You will discover that very few stimulus objects in normal life are small enough to fall completely within the foveal area and so be visually perceived without eye movement. In fact, the function of such eye movement is to get successively the image of parts of the figure upon the fovea of the eyes. For example, as you read this page, you will discover that your eyes move across each line in a series of successive "jumps" and "stops" so that successively several words or a phrase are in clear vision. Observe the eyes of someone reading and the several movements for each line from left to right with a single back sweep to the left end of the next line will be obviously apparent. The rapid reader is frequently one who can perceive a given length of printed line with relatively few stops, while the slow reader is frequently one who has to stop many times before all parts of a printed line have been clearly perceived in foveal vision. There is experimental evidence which indicates that the eye does not see at all during actual movement and that clear vision, at least, takes place only during the stops when the eye is at rest.

We come now to the third problem, that of the visual perception of depth and of distance. Solid objects seem solid—we say that they have depth. Now it has been found that this perception of the third dimension is due to a number of factors. Shading and perspective are cues of depth perception, but the principal cue is due to the fact that we have two eyes which are separated some distance in the head. Hold your finger about 6 inches directly in front of your nose with the nail directly to one side. Fixate the finger with both eyes and then, without change of fixation, close first one eye and then the other. You will find that you can see much of the nail when you look at it with the eye on that side, but when you look at

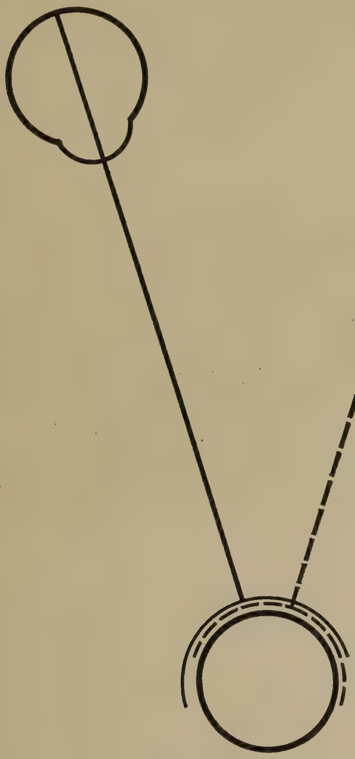

Fig. 27

your finger with the eye opposite the nail, the view of the nail practically disappears. This situation is diagrammed in figure 27. From its position the right eye looks further around the right of the object A and the left eye further around the left of this object. Each eye looks half way around the object, but because the eyes are looking from different angles, each eye sees a slightly different half. Hence the images for the two eyes are *dissimilar* and when these two dissimilar retinal images are combined, the impression is a perception of solidity.

These facts have been called stereoscopy and indicate that the coinciding of the two dissimilar images is the primary cue for the visual perception of depth. Exactly these principles are made use of in the parlor stereoscope through which you look at two flat pictures simultaneously and obtain the illusion of depth. If you will examine a pair of stereoscopic pictures, such as the ones here given in figure 28, you will find that the two pictures are different. For example, in the left hand picture, the face of the man in the background is completely covered by a bamboo stalk while in the right hand picture most of his face can be seen to the right of the stalk. These pictures are different because they were taken with two cameras set at the proper distance and the proper angle so that the right hand camera covers the object further to the right and the left hand camera further around to the left. The recombining of these pictures into a single image which gives the illusion of depth, is merely a matter of arranging conditions so that the right eye sees only the right picture and the left eye sees only the left picture. If each eye sees only its own image and these two images are combined, the illusion of depth will be apparent.

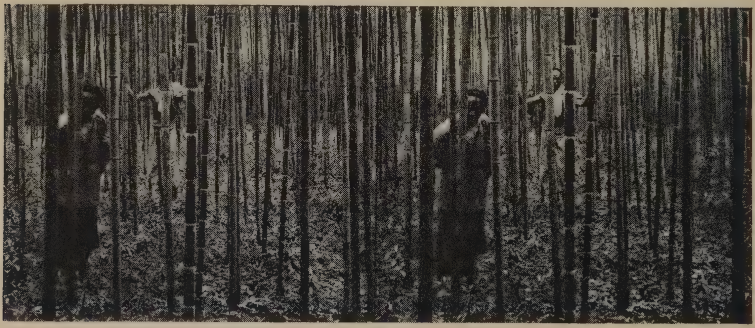

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FIG. 28

Thus, in the stereoscopic frame the essential feature is the short screen between the eye pieces. This screen keeps the left eye from seeing the right picture and vice versa. The lenses are an aid to combining the two images but are really not an essential part of the apparatus. It is perfectly possible to combine these pictures and obtain an illusion of depth without the aid of a stereoscope at all. If you will hold a sheet of paper as a screen between two stereoscopic pictures and look with the right eye on the right side and with the left eye on the left side of this screen and then fixate for distance—try to look through the book at something well beyond it—you will find, with some little practice, that the images will combine and give a perfect stereoscopic effect of depth.

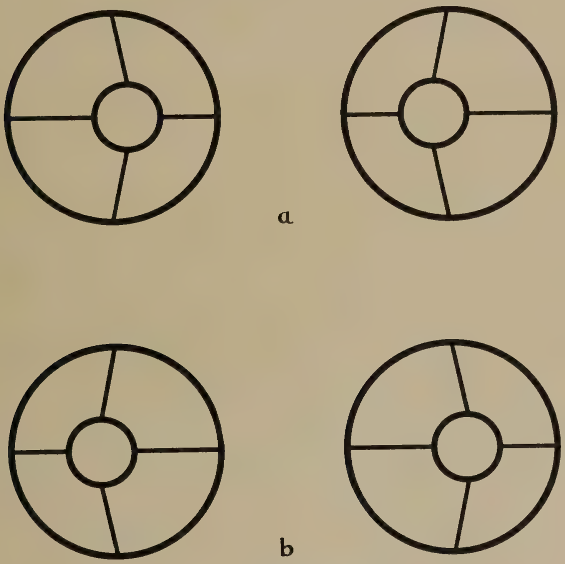

FIG. 29

Similarly, using a screen to isolate each image to each eye, examine the figures in plate 29. When combined into a single image, figure A will appear to be a cone pointed toward you and figure B will appear to be a cone pointed away from you.

These figures clearly illustrate the dissimilarity of the two images of the right and left eye and also the fact that the degree and nature of the dissimilarity of the two images determines the form of the depth perception.

The perception of distance is, of course, partly determined by the size of the retinal image. The whole of linear perspective is based upon the fact that the further an object is from the eye the smaller will be the image. In figure 30, the buildings are in linear perspective to a vanishing point and it will be seen that the greater the apparent distance the smaller the image. But what about the human figures? Obviously the one further away seems tallest and the one closest is the shortest. If you will measure the human figures from feet to head you will discover that they are all the same size. The illusion is based upon the fact that we expect an object far away to have a

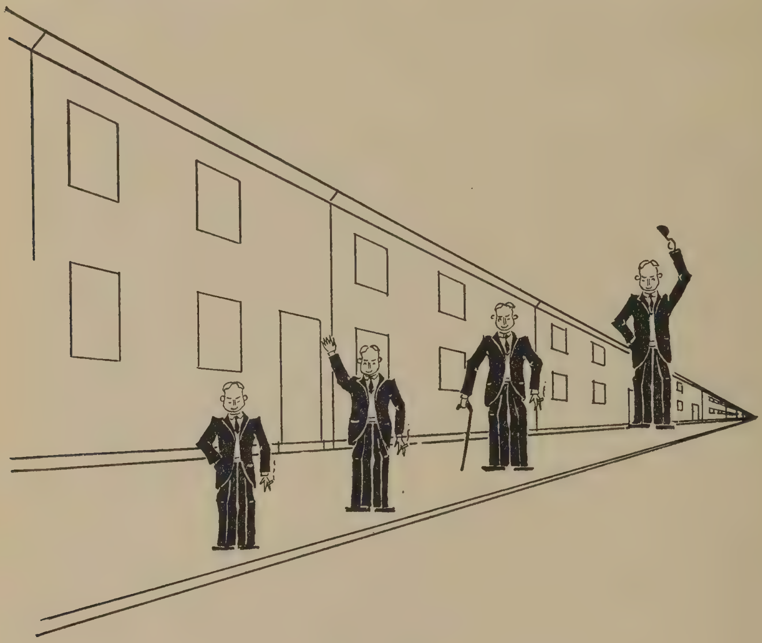

Fig. 30

smaller image than the same object close to the eye. In this picture the human figures seem to be at different distances and but still the images are all of the same size.

But much more important than the size of the retinal image in the perception of distance is a contribution from the eye muscles. The purpose of the eye movements of convergence is to focus clearly the images of the stimulus object on the foveas of both eyes simultaneously. Hence for a distant object the lines of sight are parallel or nearly so while the closer the stimulus the greater the need for more and more convergence. These facts are diagrammed in figure 31. *A* illustrates the nearly parallel lines of sight for distance vision and *B* illustrates the convergence for near vision. Experimental results have shown that distance is judged largely on the basis of the amount of pull on the nose side rectus muscles required to obtain the

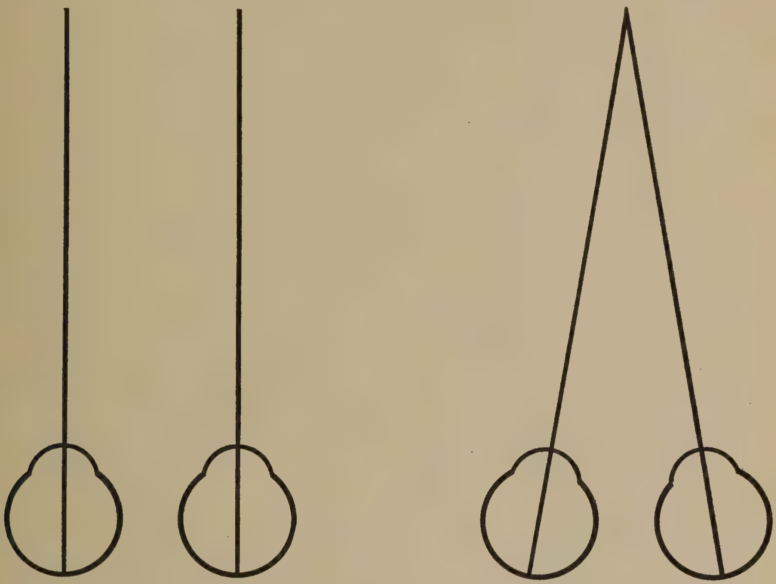

FIG. 31

necessary degree of convergence. We learn by experience to interpret the sensations from these muscles as meaning that the object is *near* when a high degree of convergence is present or *far* when there is little convergence.

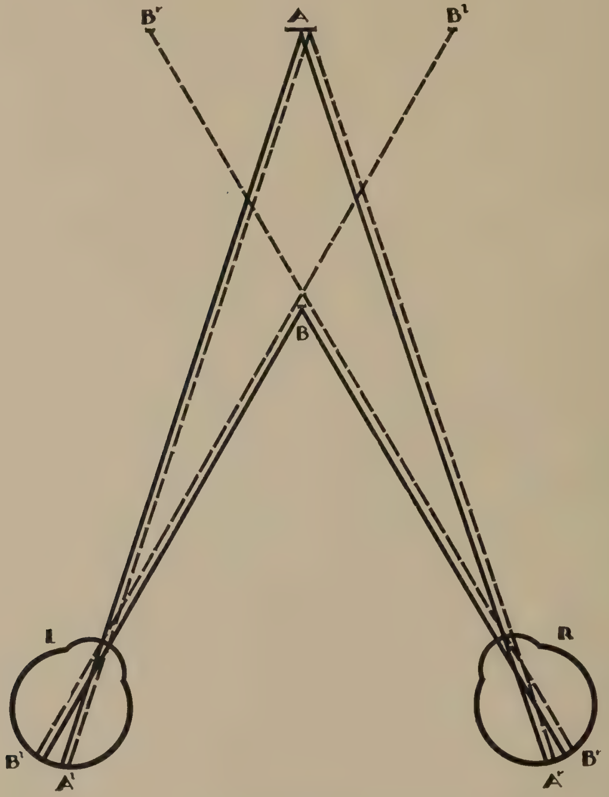

FIG. 32A

One result of this complicated situation is that all objects either closer to or farther from the point of binocular fixation actually seem double. Hold your two fingers in line with your nose, one six inches from your face and the other eighteen inches away. Fixate the near finger with both eyes and holding this fixation constant, you will observe that the far finger will appear double. Now change your fixation so that you see the further finger clearly, and the near finger will appear double. The reason for this doubling of the images of objects farther or nearer than the point of convergence—fixation are indicated in figure 32. Letter *A* represents in both figures the point of fixation and *B* the object either nearer or farther from the point of fixation. All images tend to be projected to the plane of fixation and a study of the diagrams and a tracing of the lines will indicate that all objects nearer or farther from the point of fixation are seen double.

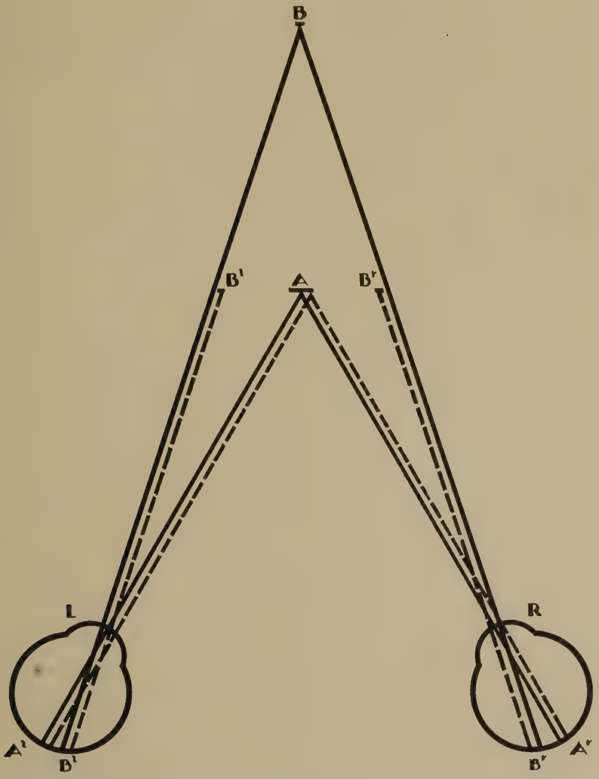

FIG. 32B

Other factors also contribute to the apparent or actual perception of distance and all of these have a background in the apperception of past experience. Interposed objects, for example, always indicate, as we know from our apperceptive background, that the object partly covered is farther away than the object covering it. This principle is illustrated by figure 33 in which the rings seem to be intertwined although they are actually printed on a flat surface, some parts seeming closer than other parts.

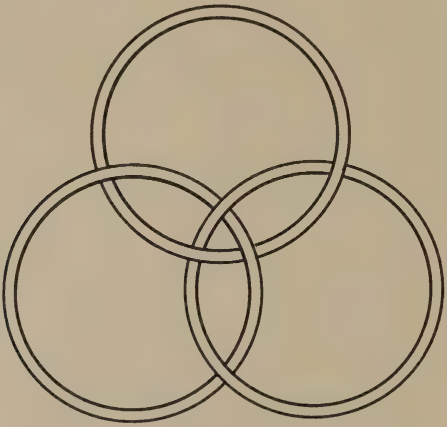

FIG. 33

Linear perspective has already been mentioned as a factor in the perception of depth. Still another factor is what has been called aërial perspective, the fact that objects distant are less clear than those close to the observer. The facts of aërial perspective are utilized by all good artists in differentiating between foreground, which is clear, and background, which is more hazy, in a painting.

What is seen as figure and what is seen as background also influences the apparent perception of distance. Figure 34 may be seen either as an arrangement of circular tiles. You can see them in many different ways; as a diamond of four tiles standing out from a background or as a single tile surrounded by a circle of tiles standing out from a background. It will be observed that the part seen as figure will appear to be closer to you and the part seen as background will seem to be further away.

The apperceptive background plays an important part in the perception of distance even though its cues are frequently so habitual that they usually pass unnoticed. Look at the picture in figure 35 of the turret of the Monitor after a battle. It obviously seems as if the shot holes were indented and the bolts come out toward you. Now turn the picture upside down and the shot holes will appear as bulges and the bolt heads as indentations. If you analyze this situation, you will discover that you have a complete apperceptive background with regard to shadows cast by the sun which is the basis for this illusion. The sun normally shines from above and so the shadow from an indentation will be on the upper part while the shadow from a projection will be below. Change the vertical relation of

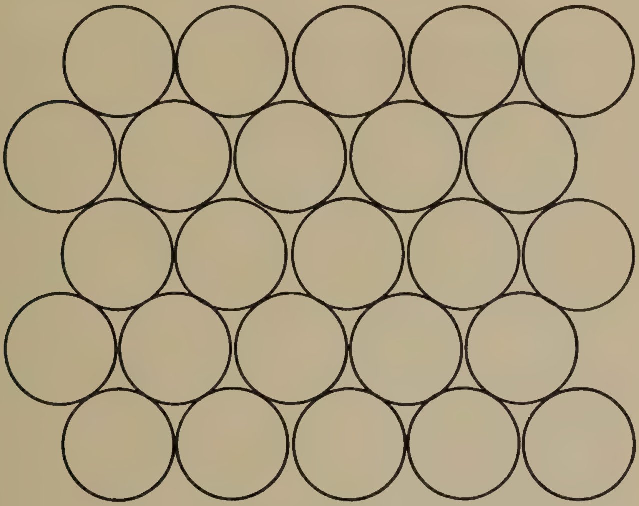

FIG. 34

shadow and the object casting the shadow, as when you turn this picture upside down, and the apparent relations of distance will be changed.

Until now we have not spoken of the psychological problem of *meaning* partly because the psychology of meaning is still in a very unsettled state and the psychological explanations of meaning are none of them complete or satisfactory. We have spoken throughout of stimulus objects as if they were meaningful objects. The relation of meaning and of mental process is by no means as clear cut as this however. For example, if you look at the accompanying figure 36 you will at once get the impression of a picture of two saints. If you analyze the lines of the figure, however, you will discover that the drawing is a most inadequate representation, not only of two human figures, but of two figures having any special religious significance. For example, examine in detail the most inadequate

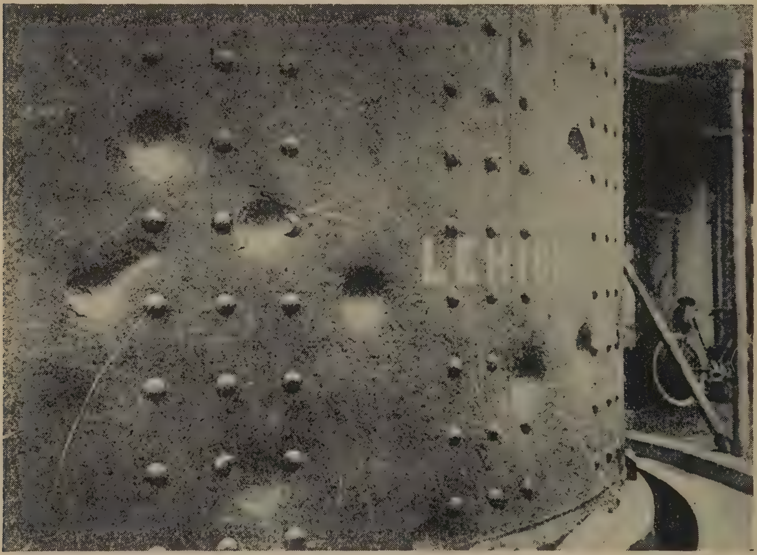

FIG. 35

treatment of the features of the faces. Thus we see that a relatively indefinite psychological process, with the adequate apperceptive background, may be very highly meaningful.

Perhaps one of the clearly outstanding examples of the effect of apperceptive background in visual perception is to be found in the visual perception of movement and of apparent movement. The moving picture gives us, perhaps, the best analysis of the visual perception of movement. The moving picture, is in fact, a series of still pictures each slightly different in a certain way from the preceding and each successively exposed for a short period of time. If an arm is moved, an examination of the successive pictures will show the arm in several different positions. The exposure of these slightly different pictures successively at the right speed gives the illusion of actual motion. In other words, if a stimulus object is in one position at a given moment of time and in another position at a given subsequent moment of time, our apperceptive background gives

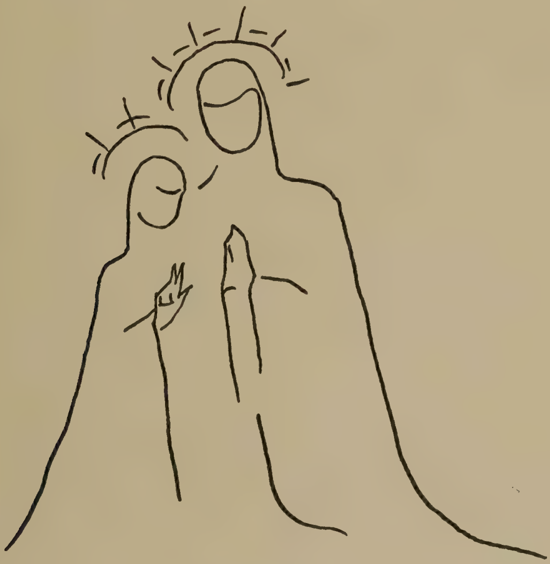

Fig. 36

the cue that this object has moved from the first to the second position.

Binocular visual perception, then appears as a very complicated process indeed in all of the three problems of the perception of shape, size and distance. Many cues of different sorts contribute to these perceptions such as the size and shape of the retinal image, the apperceptive background with the cues of meaning, interposing objects, linear and aërial perspective. But the principle cues for the visual perception of size, shape and distance are not contributed by the retina at all but by the external muscles which control the movements of the eyeballs. The sensations of these movements of direction and of convergence, necessary for the focusing of all or of parts of a stimulus object upon the fovea—the clear point of vision,—in each retina, turn out to be of paramount importance. Vision, then is as much a contribution of muscular sensations as it is of sight (retinal sensations) proper. It is almost true to say that we see as much with our eye muscles as we do with our eyes. We shall have more to say about muscular sensations in the next chapter.

QUESTIONS

1. What are the principal problems raised by binocular vision?
2. Give the important contributions made by the external musculature of the eye to tri-dimensional vision.
3. What is an illusion? What is the general type of explanation given to the visual illusions?
4. What are the principle kinds of eye movement?
5. How have the nature of eye movements and their psychology affected esthetics? Reading habits? Advertising?
6. What is the principal factor operative in tri-dimensional vision? What secondary cues are used to determine absolute size and position in space?
7. Explain the principle of the stereoscope.

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CHAPTER VI

MUSCULAR OR KINESTHETIC SENSATIONS

In the last chapter the contribution of muscular sensations to complex visual experiences was emphasized. We discovered that this thing we have called seeing is really a combination of retinal experiences proper, to which are added the experiences of muscular contraction from the muscles necessary to move the eyeballs and focus the lens. We now want to treat muscular sensations in their own right. It will be found that these sensations are exceedingly important even though they do not appear at all in the list of the five sense modalities given by Aristotle and even though they were not really recognized until less than 200 years ago.

Muscle is a collection of fibers running the long way enclosed in a sheath or covering very much like the skin of a sausage. (See fig. 37.) This sheath is gathered together at the two ends without muscle fiber and this part of the sheath is called the tendon. There are two tendons for every muscle,—one at each end. These tendons are attached to other structures. One tendon is attached to some rigid and non-movable part of the body and the other tendon is attached to some movable part of the body. In the case of the eye muscles, for example, one tendon is attached to the skull bone, which does not move, and the other tendon is attached to the eyeball which can be moved.

When a muscle contracts there is a rearrangement of the fibers within the sheath. The muscle becomes larger around and therefore necessarily becomes shorter. This can be seen in the chart below. In this chart the relaxed muscle is represented by the solid lines and the contracted muscle by the dotted lines. But the tendon attached to the rigid part of the body cannot move and hence the movable part is brought closer to it. (See fig. 38.)

At the present moment we are interested only in two kinds of muscles in the body. One kind, like the eye muscles, has one attachment on a bony structure and the other on some soft structure. The other kind of muscle has its tendons attached in both cases to bony structures with a joint between the two bones. These latter are known as the skeletal muscles. The action of the skeletal muscles is shown in figure 39 which illustrates the action for moving the elbow joint. The solid lines indicate the position of the structures when the muscle is relaxed and the dotted lines indicate the position of the structures when the muscle (the biceps) is contracted and the elbow flexed. The muscle which flexes the arm is in a relaxed state when the arm is elongated, one tendon being attached near the shoulder and the other tendon attached to the forearm. When the muscle contracts and shortens, the shoulder attachment

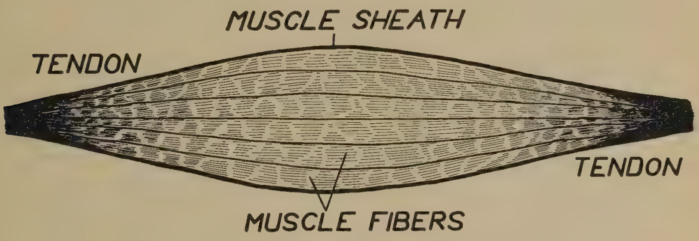

FIG. 37

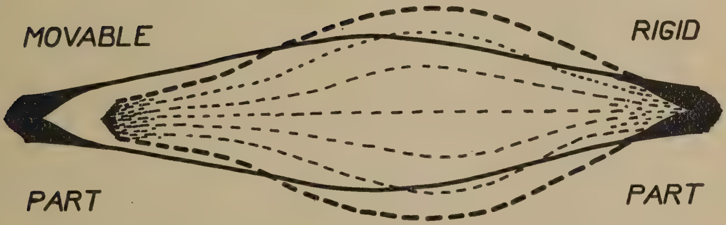

FIG. 38

cannot move and hence the forearm tendon attachment is brought toward the shoulder. This, of course, moves the joint at the elbow.

We have already mentioned in the last chapter that practically all the muscles are arranged in antagonistic pairs. One muscle contracts to move a part of the body and the antagonistic muscle must later contract to move the part back to its original position. The complete schematic picture of the muscles for flexing and straightening the forearm are indicated in figure 40. This shows the muscle in the front part of the arm whose function is to bend the elbow and the antagonistic muscle on the back of the arm whose function is to straighten the forearm. When either muscle contracts the antagonistic muscle relaxes. All normal muscles are continually in a state of partial contraction. There is a continual flow of nervous energy to every normal muscle. This gives the muscle its firm feeling —we say that a muscle has "tone." If the nerve which supplies the nervous energy to any muscle is severed, the muscle is not only incapable of being contracted but the fibers become soft and yielding to the touch and in time tend to deteriorate.

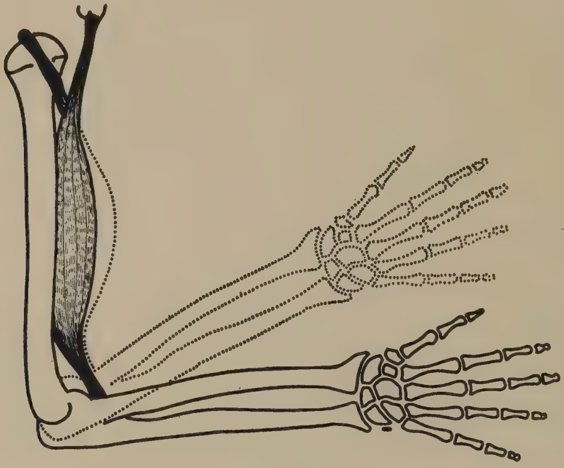

FIG. 39

So much for the simple anatomy and function of the skeletal muscles.

It has been discovered that all parts of this mechanism are supplied with sensory nerve fibers. Such sensory fibers are found in the muscles, in the tendons and in the joints. Any movement, then, will cause stimulation of all three sorts of end organs. The contracting muscle fibers will press upon the end organs between the cells of the muscle, the strain on the tendons will stimulate the end organs in these structures and the rubbing of the ends of the bones of the joint will stimulate the end organs situated between these two ends of bone. The conscious result of the stimulation of these three sorts of end organs has been called *kinesthetic sensation* or *sensations of movement.* The first syllable of the word kinesthetic comes from the same root as the words kinetic or cinema, all meaning movement. Because of the sensations from tendon and joint, the term kinesthetic sensation better describes this kind of process than the simple term muscular sensations. The kines-

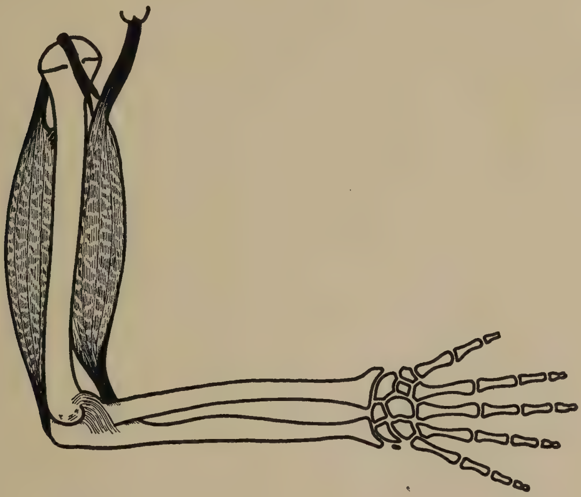

FIG. 40

thetic sensations are thus a complex either of sensations from muscle and tendon alone in the case of those arrangements in which no joint is involved (such as the eye muscles) or of a complex of sensations from muscle, tendon and joint in cases like the movement of the arm. Because of the nature of the mechanism, it is not possible, except under laboratory conditions, to get any of these three sorts of sensation into consciousness in isolated fashion. They always come to consciousness as a complex combination of either two or three sorts.

There has been a great deal of experimental work on kinesthetic sensations but the results are too technical to be presented in this place. It is known how much a muscle must contract before a sensation is aroused. It is known how different two movements must be before a difference can be reported. It must be pointed out that one is able to recognize after a given movement which muscle has been contracted and what joint has been moved. This ability is based upon the fact that the sensations of contraction of each muscle are slightly different from those of any other muscle and the sensations of the movement of any joint are slightly different from those of any other joint. These slight qualitative differences which form the basis of these judgments regarding the particular muscle contracted or the particular joint moved have been called *local sign*. As a result of past experiences one builds up a recognition that a particular local sign means that a certain muscle has contracted. Thus, for example, the biceps muscle of the right arm has its particular local sign which is different from that of any other muscle in the body.

Little more can be said regarding kinesthetic sensations without encountering technical problems beyond the scope of this text. It may be pointed out that kinesthetic sensations are highly accurate. One need only be reminded of the accuracy of judging the weight of a letter and determining whether it will go for one stamp or if it requires two stamps merely by "hefting" it in the hand. One thinks at once of the delicacy of the pianist's touch or the accuracy required for fancy figure skating. The point which we wish to emphasize is that kinesthetic experiences are very much simpler than the visual processes which have been treated before. But, in spite of this relative simplicity one cannot overemphasize the importance of kinesthetic experiences primarily *because these sensory experiences of movement form the basis of our memories of movement.*

Now there is plenty of evidence that no voluntarily initiated movement can take place without a memory of how it would feel to make that movement. Try the following experiment. Close your eyes and try to remember how it would feel to flex your right forefinger. I am sure that you will be able to call up this kinesthetic memory and you will have no difficulty in actually flexing the finger. Now try and call up a kinesthetic memory of how it would feel to move your left ear. It is the unusual person who is able to call up this kinesthetic memory of ear movement. Now try actually to move your left ear and you will discover that this is impossible unless you were first able to call up a memory of how it felt to move it. Your inability to move your ear is not, as many people believe, due to the fact that the muscle is not strong enough to move it, but rather that you are unable to contract the muscle voluntarily unless you can first call up a kinesthetic memory of how it feels to contract it.

But one can easily learn to move the ear. All that is necessary is to contract the muscle by some means or other enough times to build up a kinesthetic memory of how it feels. Experimentally this is usually done by electrical stimulation. But you can take hold of your ear and pull it backward and then allow it to go forward a number of times, paying attention to the feel of the muscle in the back of the ear, and if you do this enough times to build up the proper kinesthetic memory you will find that you have acquired the ability to contract this muscle voluntarily. In this connection the writer has had a curious experience. He once acted as a subject in just such an experiment of the acquisition of the ability to move his ear voluntarily. But the experimenter stimulated only the left ear and he built up only the proper kinesthetic memories of the contraction of this particular muscle with the result that he can now voluntarily move the left ear, but not the right one because he does not have the necessary kinesthetic memories to initiate this other particular movement.

There are certain kinds of abnormal situations where, as the result of disease or for some other reason, some of the kinesthetic memories are lost. Those muscles for which the kinesthetic memories have been lost might just as well be paralyzed so far as voluntary movement is concerned. The initiation of voluntary movement for these muscles is only recovered when a new set of kinesthetic memories is acquired through practice.

We have seen that the voluntary initiation of a movement is dependent upon the possession of kinesthetic memories and that the possession of these kinesthetic memories is in turn dependent upon previous kinesthetic sensations of that particular movement. But what about the voluntary stopping of a movement either after it has started or even to prevent its starting? The term *inhibition* has been given to both of these situations. Most people think of this inhibition as a kind of negative affair,—they believe that you just cut off the nerve supply if the movement has already started or you just never turn on the nerve supply to the muscle if you do not want the movement to start. Such a concept is entirely wrong. Inhibition is a very active process indeed. It involves the active contraction of the muscles antagonistic to those which cause the movement which is to be stopped. Try the experiment of rapidly flexing your arm and then suddenly stop the movement halfway and you will find that the antagonistic muscles on the back of the upper arm are rather violently contracted. It takes as much nerve energy and as much muscular contraction to arrest or stop a movement as it does to make a movement.

We have already warned the reader that this chapter would be short but that the shortness of the chapter is not an indication of the relative importance of kinesthetic sensations. We have seen that these sensations of movement are exceedingly important although they are relatively simple and although little can be said about them in a non-technical exposition. I can, perhaps, emphasize this point by putting to you the problem as to which modality of sensation would be most necessary at birth. If you were told that all modalities of sensation would be taken away from you but a single one, which one would you choose to retain? Certainly one can get along well in the world without vision. Many totally blind people progress and live full and happy lives although, of course, with a handicap which must not be minimized. One can get along very well indeed without hearing although this again presents a serious handicap. One could get along without either taste or smell and, after a time, the deficiency would hardly be noticed. But one could not get along at all if deprived of kinesthetic sensations from birth. Without these sensations one could never acquire a stock of kinesthetic memories and hence it would be impossible to make any voluntary movement whatsoever. Even with all of the other modalities of sensation intact it would not be possible for such an individual to move at all. From this point of view, then it would seem that these kinesthetic sensations form the most important sensory modality for human development.

QUESTIONS

1. From what anatomical structures do the kinaesthetic sensations arise?
2. What relationship exists between kinaesthetic sensation and motor activity?
3. What is the significance of the experimental work on ear movement?
4. What is meant by inhibition?
5. How do kinaesthetic sensations compare in importance with other sensations?

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Chapter VII

HEARING

The normal stimulus for hearing consists of waves in the air set up by the vibrations of a sounding body. Actually any other medium for the transmission of the waves may be as effective or even more effective than the air. Place your ear at one end of a table and have someone lightly tap on the other end. The tap will sound louder through the denser medium of the wood of the table than it will through the air. It is said that the Plains Indians in the early days of the railroads used to place their ears to the track to learn of the approach of a train long before the puffing of the engine could be heard normally.

The end organ for audition is, of course, the ear but only in the sense that the eye is the end organ for vision. We shall see that only a small part of the ear is the actual sense organ for audition and that all of the rest of the ear is merely a mechanism for getting the stimulus sound waves to the actual sense organ. A simplified diagram of the ear is given in figure 41. The external ear is, in fact, a funnel which collects the sound waves and concentrates them into the auditory canal. The form of the external ear with its folds and ridges also stops the sound waves from being reflected back and forth and so creating echos. At the inner end of the narrow part of this funnel is the ear drum (called the tympanum). This is really a very complicated organ with several sets of muscles and it forms an ideal diaphragm which is set into exactly the same motion as the sound waves which press upon it.

The tympanum is the boundary between the outer ear and the middle ear. All of the rest of the ear about which we shall speak must be conceived of as holes in the skull containing certain structures. In the middle ear there are three small bones held together with a relatively complicated arrangement of muscles. The first of these bones is connected to the inside of tympanum and moves exactly as the tympanum moves when sound waves stimulate it. This exact motion is transmitted to the second bone and then by this to the third bone and then in turn to some structures in the inner ear where we shall find the true organ of hearing.

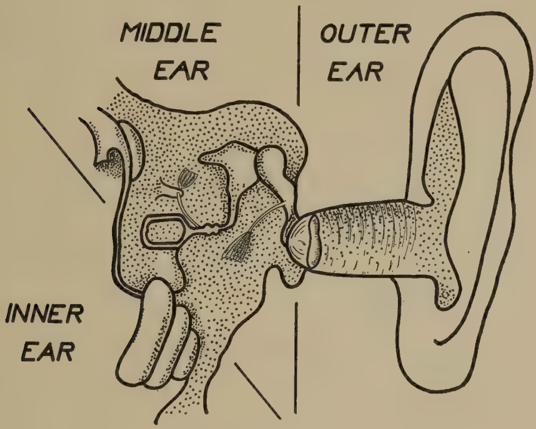

Fig. 41

In the inner ear is a structure called the cochlea and the third bone of the middle ear is attached to a membrane at one end of it. If the bones were dissolved from the skull, the cochlea would look like a small coiled snail shell with two and a half turns. The bone of the middle ear which presses against its end is stirrup shaped. The positions of the bones and of the cochlea can be seen in the chart of the ear above. If one could take hold of the two ends of the cochlea and unwind it and straighten it out, it would appear something like a sausage. A cut vertically through this the long way would give the appearance shown in figure 42. The stirrup bone is seen in position at the right against the upper end of the cochlea. Running through the middle, almost but not quite to the upper end, is a structure called the basilar membrane. All of the rest of the space inside the cochlea, except for some organs above the basilar membrane which will be described later, is filled with a fluid. Hence all movements in the fluid will set up similar movements in the basilar membrane. Let us now see what the cochlea would look like if it were cut through vertically as one slices a sausage and then look at it from the end. This is shown in figure 43.

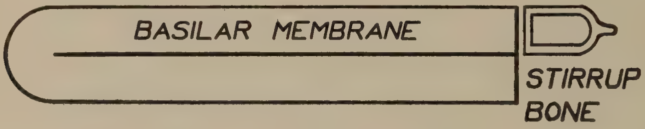

Fig. 42

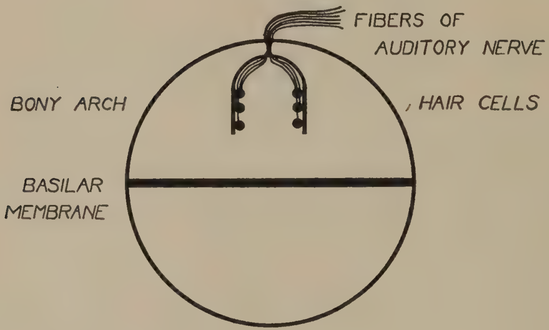

Fig. 43

It will be seen that the basilar membrane extends completely across the cochlea. Above the cochlea is a series of some thousands of bony arches only one of which is shown in the chart. Each of these bony arches contains nerve cells (called the hair cells) the fibers of which break through the cochlea, and when gathered together, form the auditory nerve.

These hair cells are then the true end organ of hearing and all of the rest of the structures of the ear consist merely of means for getting the stimulus sound waves to these end organs. The situation is exactly like that of the eye where the retina is the real end organ of vision. The rest of the eye and the rest of the ear are purely accessary but very important structures. For audition, then, the sound waves are gathered by the external ear, are concentrated in the auditory canal, and there set the tympanum in motion. This motion is successively transmitted to the three bones of the middle ear, to the fluid in the cochlea and to the basilar membrane which presses against the hair cells, the true end organs of hearing. In these hair cells the waves of physical energy are somehow translated into nerve energy which travels along the auditory nerve to the brain.

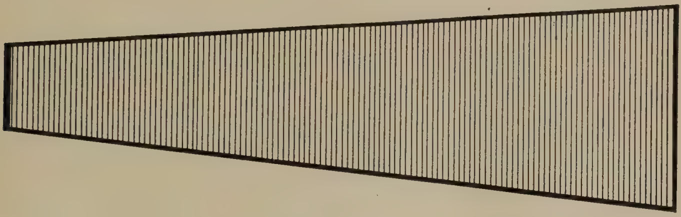

FIG. 44

When this nerve energy reaches certain parts of the brain then, and only then, do we have auditory sensation,—the consciousness of sound.

Just what happens in the cochlea is not well understood and the physiologists and psychologists are divided between two types of explanation. If the top of the cochlea should be cut off so that one may look down upon it, the basilar membrane would seem to have the form given in figure 44. The fibers run crosswise, it will be noted, and there are some thousands of such fibers. One group of auditory theories insists that each of these fibers, like the strings of a piano which they resemble, is tuned to a particular tone and that when this tone is given the particular fiber alone vibrates and presses against the hair cells directly above it. The other type of auditory theories insists that the basilar membrane always vibrates as a whole to all of the different tones and that it is the rapidity and the pattern of this vibration against the whole group of hair cells which is the basis of tonal differentiation.

The following interesting experiment has been performed within the last few years. It has been discovered that the nerve currents accompanying the passage of nerve energy along any nerve may be picked up by a delicate radio apparatus, and when greatly amplified, may be used to actuate a loud speaker. In this experiment, the investigators anesthetized a cat and then very carefully performed a mastoid operation removing the bone at the back of the ear and exposing a section of the auditory nerve without injuring either the nerve or any of the structures of the ear. One wire electrode was attached to this auditory nerve and another electrode was grounded by sticking a needle attached to another wire into the cat. It made no difference where the second needle was placed. These wires were then strung to the other end of a long building where they were attached to a powerful amplifier which was in turn attached to a loud speaker. The experimenters hoped that a normal stimulation of the cat's ear with sound waves would set up electrical currents in the auditory nerve which might give them a click in the loud speaker. One can imagine their surprise, therefore, when it was found that any sound stimulating the cat's ear was adequately and exactly reproduced through the loud speaker. It was found possible to use this arrangement as a one-way telephone in which the cat's ear was the mouthpiece and the loud speaker was the receiver. When the cat died or when the blood supply was cut off from the auditory nerve, the stimulation of the cat's ear no longer set up the necessary nerve currents in the auditory nerve, thus indicating that the experimenters were dealing with a real phenomenon of hearing. This experiment still does not explain what happens between the basilar membrane and the hair cells but it clearly indicates that nerve currents are set up in the auditory nerve which are exact reproductions of the waves of the stimulus.

The physical wave for a pure tone, that is a single pitch unmixed with other pitches, is what in physics is called a pure sine wave. Sound waves may vary in each of three ways and each of these variations is the basis for a difference in auditory sensation.

In the first place sound waves may vary in rapidity or frequency. Two waves varying in frequency but similar in all other respects are given in figure 45. The wave represented by the dotted line has more crests over a particular period of time, and is said to have a greater vibration frequency than that represented by the solid line. This difference in vibration frequency is the basis for differences in the pitch of the auditory sensations. The more rapid the vibrations, the higher is the pitch. These differences in pitch are the basis of the musical scale. The middle C of the musical scale is usually given at 256 vibrations per second, that is, 256 impacts of air waves in the tympanum each second. The arrangement of octaves in our musical scale is on a purely mathematical basis in which each higher C has a frequency of just twice the number of vibrations each second of the C below. Hence if middle C is represented by a frequency of 256 vibrations per second; the C^1 will have a frequency of 512 and the C^2 a frequency of 1024 vibrations per second.

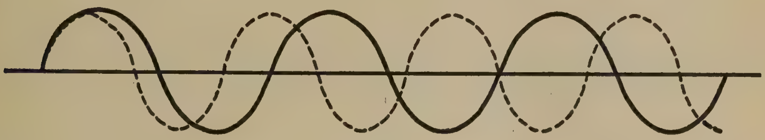

FIG. 45

It has been found that there is considerable individual variability in the limits of hearing, the limits above and below which air vibrations do not produce auditory experiences. In very large church organs the lowest pitched pipe is 24 vibrations per second. For some individuals the stimulation by this pipe alone is merely felt as a rapid series of pressures against the ear drum and is not heard as sound at all. A safe estimate for the lower limits of hearing is about 20 vibrations per second. On the whole stimulations of the tympanum at a rate slower than this will not be heard while those more rapid will be heard as tones.

There is even more individual variation regarding the upper limits of hearing. But a safe average in round numbers is about 20,000 vibrations per second as the upper limit for tone. Some people cannot hear sounds above 14,000 vibrations per second while other individuals can hear sounds as highly pitched as 30,000 or even close to 50,000 per second. There is an instrument for testing the upper limits of hearing which consists of a series of metal cylinders each tuned to a very high pitch. There are set into vibration by hitting them with a small metal hammer. If one starts at the lowest pitch of this instrument and proceeds upward one has successively the auditory experience of running up a very high pitched musical scale until his upper limit of hearing is reached and then all higher cylinders seem to give exactly the same auditory experience. For these higher tones beyond the limits of hearing all appear to have only the same dull thud as the hammer strikes the cylinder. There is clear evidence that some of the insects make sounds and are able to hear sounds far beyond the upper limits of the range of human hearing.

Experiments indicate that between these limits of 20 to 20,000 vibrations per second the average normal ear can distinguish approximately 20,000 differences in pitch. These differences are by no means evenly distributed throughout the pitch scale however. The lower end of the audible scale is relatively insensitive and one may have to have a difference of a vibration or more each second before a tone of 22 vibrations per second could be differentiated from the next higher. The upper end of the scale is even less sensitive and a tone of 19,300 might not be differentiated from one of 19,332—a difference of 32 vibrations per second. The central part of the scale, however, is relatively more sensitive. And especially is this true between approximately 150 to 4,000 vibrations per second. Within this range differences may be noticed that are represented by as little as one-fourth of a vibration per second. It will be noted that this range of best discrimination is the most commonly used range in music and that it is the range of the human voice.

There are some individuals with such a high degree of native sensitivity and who are so well trained besides that they are said to possess what is called *absolute pitch*. Such individuals are able to discriminate and correctly name any note played on any instrument or any note which they hear sung.

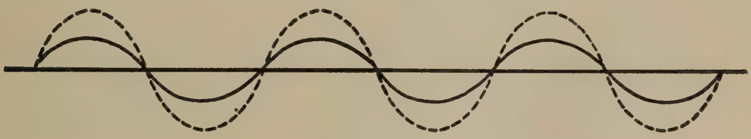

Fig. 46

The second way in which sound waves may vary is in amplitude. The two waves in figure 46 vary in amplitude but are similar in all other respects. It will be observed that the two lines have the same frequency—the same number of crests but that the dotted curve is of much greater amplitude in that it extends further from the line of rest than the solid curve. Differences in the amplitude of the sound wave are the basis for differences in the intensity or loudness of the sound heard. The greater the amplitude of the sound wave the greater will be the intensity or loudness of the heard tone. Obviously the wave with great amplitude would press the tympanum in further than the wave with little amplitude and so it would set up greater and more extensive waves in the auditory system. For every pitch, it has been found that one may discriminate a large number of intensity differences but the discussion of this problem in greater detail would be too technical for treatment in this text.

The third way in which tones may vary is due to the differences in the form of the sound wave. Such variations may be diagrammed (fig. 47) in which the dotted line is the simple curve and the solid line represents a complex sound wave showing a number of secondary crests and troughs. The differences in the complexity of the wave form is the basis for differences in the quality or *timbre* of the auditory experiences. A tone played on a violin and a tone played on a trumpet may be exactly the same in pitch and in intensity but the quality or timbre of the two tones will never be confused. Even though the wave forms of the tones from these two instruments may have exactly the same frequency and the same amplitude, they will differ in the complexity of wave form.

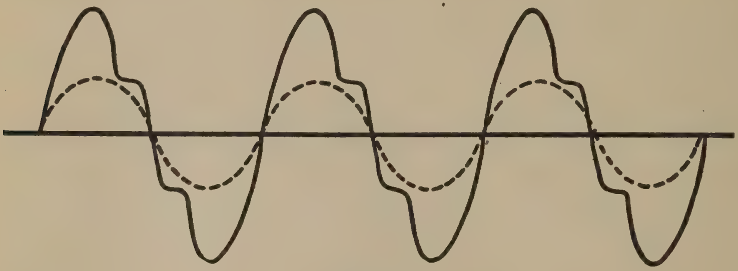

FIG. 47

In the previous discussion of pitch and intensity we have spoken of the wave form as if it were a pure sine curve. Such a pure sine wave would give one a pure tone. In actual experience it is very difficult indeed to obtain a pure tone in which only one vibration frequency is represented. Every ordinary tone is complex and each consists of a *fundamental* tone, which we ordinarily say is the pitch of the complex, and a series of *overtones*. These overtones are all higher in pitch than the fundamental and are of less intensity. They are caused by the sounding body not only vibrating as a whole but also vibrating in parts. It vibrates, for example, in halves which gives the first overtone which has double the vibration frequency of the fundamental and therefore represents a tone one octave above the fundamental. It vibrates in thirds and so the second overtone has three times the vibration frequency of the fundamental and is the G above. The body vibrates in fourths and hence produces the third overtone which is two octaves above the fundamental with four times its vibration frequency. Hence if the middle C should be tuned to 261 vibrations per second, this would be the fundamental and the overtones would be as indicated in the following table:

Fundamental	C	261
First overtone	C^1	522
Second overtone	G^1	783
Third overtone	C^2	1,024
Fourth overtone	E^2	1,306
Fifth overtone	G^2	1,566
Sixth overtone	B^2	1,827
Seventh overtone	C^3	2,088
Eighth overtone	D^3	2,349
and so on		

One investigator claimed that he was able to sit before a small organ and identify more than 30 overtones of a given fundamental. One of the differences between a fine voice and a poor one is that the fine voice is very rich in overtones and the poor voice has fewer overtones. In practice in auditory experiments, in order to obtain a pure tone, it is necessary to filter out with a very complicated apparatus all of the overtones, leaving the fundamental alone. Such a pure tone sounds very "thin" even though it has plenty of intensity. The difference between the timbre of two instruments playing a tone of the same pitch and intensity is the difference in the emphasis of different sets of overtones. The form of the construction of a violin emphasizes one group of overtones and suppresses others while the form of construction of a cornet emphasizes another group of overtones and suppresses some of the others.

An ordinary complex tone with its fundamental and its overtones is then really in the nature of a tonal mixture. And we have seen from the table above that the numerical ratios of the vibration frequencies are simple in such a mixture. When two or more complex tones are sounded together they will also mix to give what has been called a *chord*. The simpler the numerical relations between the frequencies of the sounded notes the more complete will be the mixture. Hence the octave represents the simplest relationship because the higher fundamental corresponds to the first overtone of the lower tone; the first, the second and third overtones of the higher fundamental correspond to the third, fifth, and seventh overtones of the lower fundamental. These relations can be seen from a study of the table of overtones above.

Further discussion of this topic would lead too far into the theory of musical composition for treatment here, but it may be said that in all mixtures which may be classed as harmony, there is a simple mathematical relationship between the vibration frequencies of the component tones and their overtones. If this simple relationship of vibration frequencies is lacking, the resultant tonal mixture is called discord. As in the case of color mixture it is possible to analyze a tonal mixture and to identify the several component tones. A trained musician is able to tell you which tones are the components of any chord.

On the basis of this discussion it is simple to analyze the distinction between tone and noise. Tone we have found to be an experience caused by a relatively intensive fundamental with a number of less intensive overtones whose vibration frequencies are in a simple mathematical relationship to the fundamental. Noise is a complex of tones in which there is no prominently intensive fundamental and in which the components have vibration frequencies which are not in a simple mathematical relationship to one another. But it is possible to analyze any noise into its components and to determine that each of these is a tone with a clear and identifiable pitch. There exists a series of instruments each constructed to intensify a given pitch. In the presence of a noise, if the instruments of this series are held successively to the ear, one may determine the different pitches of which the noise is composed. One may determine the tonal constituents of a noise by the following simple experiment. Cut a number of different lengths of hard wood and throw them on a bare floor together. The result will very definitely be a sound that you would describe as noise. Now, if you will throw the sticks on the floor one at a time, you will discover that each, in striking, gives a tone of definite pitch.

If two tones which are not very different in vibration frequencies are sounded together it will be discovered that the sound seems to continually swell in intensity and then decrease over and over again. It will be found that the number of increases in intensity per second is equal to the difference in the vibration frequencies of the two sounding tones. This has been called the phenomenon of *beats*. Hence, if two tones have frequencies of 250 and 251 vibrations per second, there will be only one beat per second,—or the difference in the frequencies of the two tones. If the original frequencies are 250 and 256 vibrations per second there will be six beats each second.

Beats cannot be heard in very great frequency. When the frequency of the beats increases to about 20 per second, approximately the number of vibrations of the lower limits of hearing, it is found that the beats disappear, and if one listens carefully, he is able to discover a very low tone which has a vibration frequency equal to the difference in the vibration frequencies of the two original fundamentals. This is called the *difference tone*. For example, if a tone of 250 and one of 290 vibrations per second were sounded together, one would be able to hear a very low tone of 40 vibrations per second which had a frequency of the difference between the other two. Some investigators insist that they can hear other difference tones which are due to rather complicated differences in the vibration frequencies of the fundamentals and overtones of the two notes sounded simultaneously. It is claimed that expert organists are able to obtain more tones than the number of keys struck by utilizing the difference tones and so are able to obtain very low notes in the tonal mixture without striking low keys at all.

It has also been claimed that when two notes are struck together one can hear a *summation tone* which has a vibration frequency equal to the sum of the two fundamentals. Hence if notes of 250 and 300 were struck together, it is claimed that one may hear a tone, higher than either of the other two fundamentals with a vibration frequency of 550 vibrations per second.

There are no phenomena in audition which correspond to the after-images in vision. Contrary to the visual experience, when a tone ceases, it is not followed by any positive or negative tonal after experience. Not immediately, but in a very small fraction of a second after stimulation ceases, the conscious tonal experience ceases also. This fact has been used by some authors to differentiate vision as a chemical sense and audition as a mechanical sense. In a mechanical sense one would expect the conscious experience to cease with the cessation of stimulation. But in a chemical sense one would expect some conscious after-affect while the chemical substance in the sense organ, changed by stimulation, returned to its former chemical state of equilibrium. This view is strengthened when we discover that in audition there is also no phenomenon of sensory adaptation, such as we find in vision. If we look at a color for a long time it gradually loses its colorfulness. But in the presence of a long continuous sound the conscious experience is just as intensive and vivid after a long period as it was when the stimulation began.

In audition, however, one finds an abnormal condition which somewhat corresponds to color blindness in vision. This is the abnormal condition of *tonal islands*. An individual suffering from this defect may be able to hear perfectly all tones from the lower limits to those of 500 vibration frequency. He may be able to hear all tones perfectly from those of 900 vibrations per second to the upper limits of tonal sensitivity. But he will be totally deaf to all tones between the vibration frequencies of 500 to 900 per second. Tonal islands have been explained in several ways but each explanation depends upon one's acceptance of a particular theory of audition and we have already indicated that auditory theories are in such a situation that the objective experimental evidence does not yet exist for the unquestioned acceptance of any one type. One can presumably be sure that tonal islands are caused by the destruction of some part of the auditory mechanism or by its failure to develop because once an individual has a tonal island he seldom, if ever, recovers from the condition.

Finally, much experimental work has been done on the problem of the localization of sounds in space. One is able to tell if a tone has been sounded to one's right or to one's left; in front or behind one. But the results show that *auditory localization* is much less exact and much less correct than the visual localization of an object in space. In fact the localization of a sound in the median plane of the head turns out to be very difficult indeed and to be extremely inexact. In such a situation errors are frequently so great that one may insist that a sound in front is coming from the rear and vice versa.

The basis of auditory localization, and the reason why localization judgments in the median plane of the head are so inexact, is because we have two ears for hearing which are separated from each other by the width of the head. Investigators have shown that these judgments of the position of a sounding body in space are due to differences in the intensity of a sound in the two ears and to differences in the phase of the vibration curve as it strikes the two ear drums. If a sounding body is to the right, the right ear will hear it louder and leading in phase than the left ear. But when a sounding body is in the median plane of the head and especially when it is exactly equally distant from the two ears, such intensity and phase cues will be lacking and the judgment of localization may become little more than a guess.

QUESTIONS

1. What is the stimulus for audition? What is the end organ for audition?
2. Give briefly a summary of the two theories current today which explain audition.
3. What experiments have been performed to determine which theory is the better?
4. In what way are the various attributes of tone such as pitch, intensity, and timbre related to the physical characteristics of the stimulus?
5. What is the range of normal hearing?
6. What is absolute pitch?
7. What is the difference between tone and noise?
8. What are tonal islands? Of what significance are they for auditory theory?
9. In what way are we enabled to determine the point from which sounds originate?

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Chapter VIII

TASTE AND SMELL

The modalities of taste and smell are here treated together in a single chapter because the conscious effects of both are so often confused in everyday experiences. We speak of the differences of the taste of roast beef and of lamb; we talk of the differences of the taste of potatoes and of onions. One basis for this confusion is the close proximity between the organs of smell at the top of the nose and the organs of taste in the tongue. And it must not be forgotten that there is a direct connection between the mouth and the nose through the skull. This can be seen in figure 51 as the passage marked the naso-pharyngeal. Hence, if one wishes to study taste alone without any contribution from smell, it is not only necessary to plug up the nostrils but it is necessary to plug up the naso-pharyngeal passage as well.

If this is done and the organs of smell are completely blocked off, it will be found that it is not possible to differentiate tea from coffee. It will be found that they taste the same, but each has its characteristic *odor* which differentiates them. If small cubes of apple, potato and onion are successively placed upon the tongue and the subject is not allowed to get cues of the differences in texture by chewing, these three substances cannot be differentiated by taste alone. It will be found that all three of them taste slightly sweet. As a matter of fact, nature sometimes performs this experiment for us, by blocking off the organ of smell when we have a cold. How often have we remarked, when we have a cold in the head, that "Food does not taste right." As a matter of fact, in this situation you should say: "Foods taste the same, but I am not able to obtain the usual characteristic smell!" For example, the enjoyment of celery is exceedingly complex with a very small contribution of actual taste. Celery either tastes slightly sweet or slightly bitter depending upon the kind of celery it is. But celery has a very characteristic odor which is usually considered pleasant. It is also usually served cold which stimulates the temperature end organs. Also good celery is crisp and part of the enjoyment of eating it is contributed by the kinesthetic and tactual sensations of chewing. And finally, part of the enjoyment of eating celery comes from the fact that you can hear yourself eat it. The expression: "I like the taste of celery" is thus based on a combination of sensations from temperature, smell, kinesthesis and audition with a very small contribution from taste proper. And indeed the almost universal use of salt with celery actually kills the characteristic sweet or bitter taste but does not effect the sensations from the other contributing sense modalities.

Let us first consider the modality of taste alone. This modality involves what have been called the *gustatory* sensations. These are caused by a chemical stimulation of the gustatory sense organs. The chemical stimulus must be a liquid or some chemical in solution. Any chemical which is not soluble is tasteless. Quartz stone is tasteless because it is not capable of being dissolved by any of the usual liquids. It happens that the saliva in the mouth, in which most taste stimuli are dissolved, is one of the finest solvents known, inasmuch as more kinds of chemical substances will dissolve in it than in almost any other known liquid.

If you will examine the surface of your tongue you will find that it is covered with minute ridges. A very much enlarged cross section of several of these ridges is shown in figure 48. It will be seen that there are deep grooves on each side of every ridge. The elevated part between two grooves is called a taste bud. The side walls of the taste buds on each side of the grooves are seen to be plentifully supplied with the nerve cells which are the true organs of gustation. The fibers of these nerve cells will be seen to collect and form the gustatory nerve, which carries the nervous energy to the brain. The stimulus, which is a chemical in solution, gets into the grooves between the taste buds and so stimulates the end organ nerve cells. This fact makes taste experimentation very difficult and very unpleasant. Mere rinsing of the mouth between taste stimulation will not completely remove all of the saliva with the previous stimulus from the bottom of the grooves. Actual drying of the tongue is necessary to remove all traces of the former stimulation.

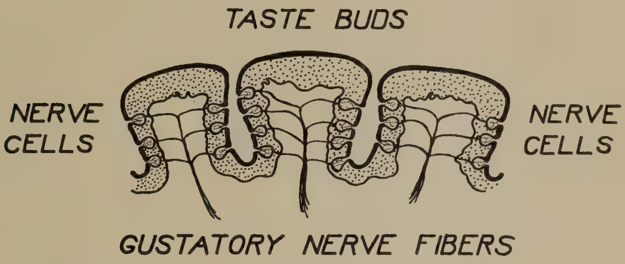

Fig. 48

It has been found that there are only four totally different taste qualities; sweet, sour, salt and bitter. All other gustatory sensations are mixtures of these four. Sample stimuli which will give the characteristic sensations of these four qualities are:

Sour	Weak hydrochloric acid
Salt	Common salt
Bitter	Quinine
Sweet	Cane sugar

A great deal of experimental work has been done on the concentration of solutions of these characteristic stimuli and of many other chemicals as well necessary to arouse a sensation. In addition the problem of the concentration necessary to arouse two sensations which will be judged different in intensity has been studied.

It has been found that the entire surface of the tongue is not equally sensitive to all of the four qualities of taste sensation. The findings are indicated in the chart of the upper surface of the tongue (fig. 49). Although slightly sensitive to the other taste qualities, the tip of the tongue is especially sensitive to sweet. When you eat a piece of chocolate you will discover that you are apt to press the tip of your tongue to the roof of your mouth. This presses the solution of chocolate into the grooves between the taste buds at the tip of the tongue where most of the end organs for sweet are located. The end organs for bitter are located largely at the root of the tongue. If you place raw quinine or any other bitter substance on the tip of the tongue you will discover that it is practically tasteless. But when you swallow the quinine you will discover, as it passes the root of the tongue, that it will suddenly seem bitter. The sides of the tongue are relatively sensitive to sensations of sour and salt. The central part of the tongue is practically insensitive to all forms of taste stimulation.

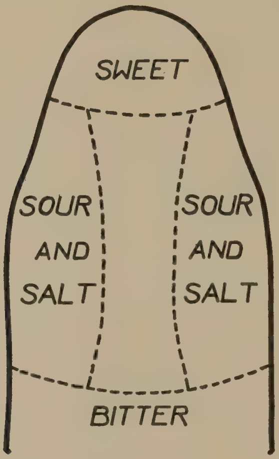

Fig. 49

The number of perceptibly different taste sensations has never been adequately determined by experiment. One can say that there are a great many mixtures of the four totally different qualities taken in pairs or in threes, but not *how* many. The relations of the four taste qualities have been diagrammed in figure 50 which is pyramidal in form. One quality is placed at each corner and the entire manifold of taste experiences is found on the surface of this figure which must be considered hollow. Salt is placed at the top because it seems to have a great cancelling effect on all of the other three qualities.

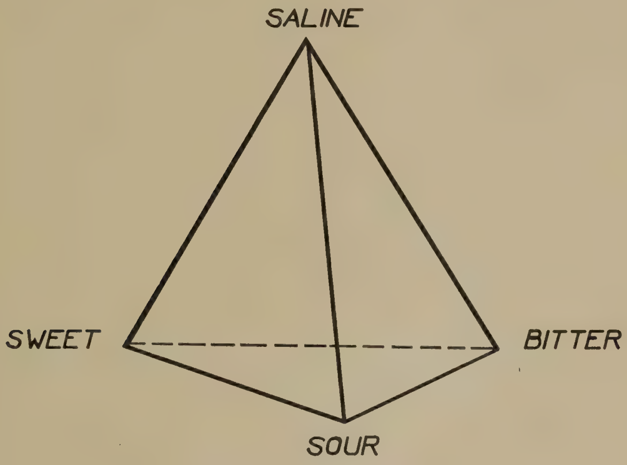

FIG. 50

There are two kinds of taste mixture. In the first type several qualities blend together as in the combinations of sweet and sour found in many of our foods. Subjectively such a mixture or blend can be analyzed and the component qualities differentiated. The second kind of taste mixture is of two qualities which tend to cancel one another. Thus we put sugar in our coffee to decrease the bitter taste of the coffee itself. In the manufacturing of pickles, the vinegar is necessary for the preservation of the pickle and then salt is added to cut down the sourness of the vinegar. But some people do not like even this amount of salt and sour and hence, in some pickles, sugar is added to partly cancel the sensations of both of these qualities.

For taste sensations, continued stimulation leads very quickly to sensory adaptation. After a short time stimulation by any of the four qualities or of any of their mixtures will lose in effectiveness until a given concentration of stimulus, which formerly was effective, will no longer arouse a sensation. There exist the length of time necessary for complete adaptation of a large number of concentrations of many different substances but their inclusion does not seem necessary here. The phenomenon of taste adaptation is familiar to many. There are people, for example, who like an oyster stew very salty. Such individuals will salt their stew before they start to eat it. After some of it has been eaten the sensory adaptation will have made this concentration of stimulus no longer effective and so they will add more salt to increase the concentration of the solution and thus the stew will again taste salty. There is some evidence, but not entirely clear cut, that this sensory adaptation in taste leads to sensory contrast. Thus if the tongue has been adapted to sweet, it seems that it is more sensitive to some of the other gustatory qualities.

In spite of the facts of rapid sensory adaptation in the modality of taste, there is no evidence of a sensory after-image such as we found in the case of vision. Certainly there is nothing in taste which corresponds to the negative after-image. Continued stimulation to sour, for example, is never followed by an after-experience of sweet, salt or bitter without actual stimulation by one of them. It is possible that there may be a positive after-image but it is not possible to demonstrate this because of the continued stimulation of the end organs by the traces of the solution left in the bottom of the grooves alongside of the taste buds.

A few years ago a very complex chemical substance was discovered which indicates that there may be certain taste deficiencies which more or less correspond to color blindness in vision. Some individuals find this substance extremely bitter—indeed some describe it as the bitterest thing that they have ever tasted—while other individuals find it entirely tasteless no matter with what degree of concentration they are stimulated. In a recent experiment a sex difference became apparent in the ability to taste this substance when approximately 500 each of men and women were tested. The results showed that the male and female groups reported as follows. The results are given in per cent of the cases.

	Men	*Women*
Tasteless	30	23
Mildly bitter	24	17
Extremely bitter	46	60

These results indicate that there were more men than women having either total or partial taste deficiency, i.e., who found the substance either entirely tasteless or only mildly bitter. Although not nearly so marked as the sex difference in color blindness in vision, some recent genetic experiments indicate that this taste "blindness" is inherited in more or less the same way as color blindness, more largely by the male through a female who is less apt herself to be taste "blind."

For the modality of smell, called *olfaction*, the stimulus is a chemical in the form of a gas. No chemical which will not volitalize is effective as an olfactory stimulus. Many years ago an investigator performed the crucial experiment to establish this fact. Although he was then an old man, he had some of his students stand him on his head, and in this most uncomfortable position, they filled his nasal cavity with an ordinarily highly odoriferous liquid. Hence the liquid and not the gas from it stimulated the end organs of smell and the investigator was able to report that under these conditions this substance was without odor.

The end organs for smell are a group of nerve cells situated at the top of the nose. Figure 51 indicates their situation as well as the air passages by means of which the gases may stimulate the nerve endings. The drawing shows both the nose and mouth regions in cross section and the bony parts of the skull are indicated by cross hatching. It will be seen that the gases may stimulate the end organs at the top of the nose by means of either of two pathways indicated by the arrows: directly up the nose or indirectly through the mouth and up the nasopharyngeal passage in back of the nose.

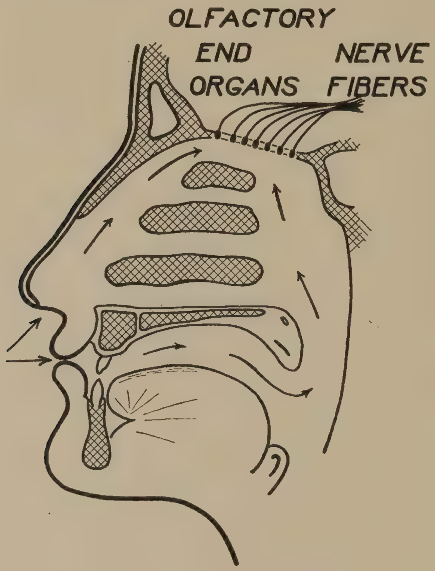

FIG. 51

Psychologists are by no means unanimous in their opinion regarding the number of totally different olfactory qualities. The classifications offered range from two to nine totally different experiences. One widely accepted classification of odors is based upon six totally different experiences. These are called spicy, fruity, flowery, resinous, burnt and foul. They are conceived as being interrelated as in the prism shaped figure (fig. 52). The six totally different qualities are put at the six corners. This prism is to be considered as a hollow figure in which all of the smell combinations are on the outside surface. Something over 300 odors have been localized at one point or another on the surface of the prism. Familiar odors

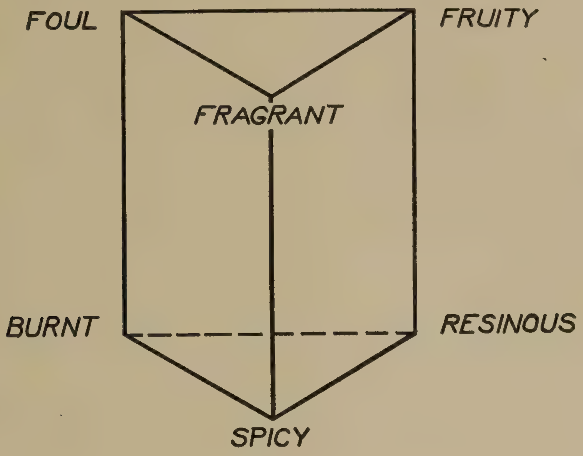

FIG. 52

which correspond to the totally different experiences are given as follows:

Foul	Decayed animal matter or hydrogen sulphide
Fragrant	Violet
Fruity	Lemon
Burnt	Tar
Spicy	Nutmeg
Resinous	Balsam

Psychologists are also by no means agreed regarding the number of perceptibly different smell qualities. There are certainly very many such but there has not yet been the experimental work to determine how many. Much experimentation exists which has determined the concentration of gases necessary to arouse sensations for many chemical stimuli. But again it seems unwise to give the data from these highly technical experiments in the present place.

Olfactory mixture exists in two forms. There exist odors which, when mixed in the right proportions, cancel one another. It has been found that Balsam of Peru and iodoform offset the odor of each other. Carbolic acid is used in medicine primarily as an antiseptic but also because its odor neutralizes the odors from decayed animal matter. It has been found that there are also odors which, when mixed together, give a new odor which is different from that of any of the constituents. These mixtures exhibit great relative stability, and in many cases, defy subjective analysis. This formation of an exceedingly stable mixture of odors is the principle made use of in the perfume industry. Many of the flower perfumes do not contain any of the essence of the flower they are supposed to represent. A heliotrope perfume can be made, for example, by a mixture in the proper proportions of vanilla, rose, orange-flower, ambergris and almond. In fact many of these perfume combinations or mixtures do not resemble the odor of any natural flower and they are given invented trade names. Olfaction is, indeed, one of the few modalities of sensation in which we may expect new experiences. It is not possible to imagine a new color mixture or a new tone. But with the relatively stable olfactory mixtures and with the breeding of new fruits and flowers, the number of perceptibly different olfactory sensations is increasing.

Sensory adaptation to smell is well known and it turns out to be relatively rapid and exceedingly complete. Continued stimulation by any odor very soon makes that odor ineffective. One has had the experience of entering a room and has found the odor of tobacco smoke, or some other odor, very strong. But after several minutes in the room with the continued stimulation, not only is the odor no longer noticed but one is no longer able to smell it even if one tries. The olfactory adaptation to this particular odor is complete. Adaptation times have been worked out for a number of substances and invariably they prove to be rapid. For example, it has been found that if the end organs are stimulated by a strong odor of asafoetida (which at first seems very strong and penetrating) for only one and a half minutes it becomes entirely inodorous. In spite of the very complete and rapid sensory adaptation to odors there is nothing in the field of olfactory sensitivity which corresponds to the after-image in vision. When the stimulation has been completely removed by drawing fresh air into the nasal passages, the conscious experience of odor entirely disappears and it is followed neither by a continuation of that odor nor by any other presumably complementary odor.

There does not seem to be any abnormal condition for olfaction which corresponds to color blindness in vision. No cases have been reported who are unable to smell fruity odors, for example, but who can smell all others. But there are very wide individual differences in the sensitivity to odors. This is true among men and becomes quite apparent if one compares the olfactory sensitivity of man with that of some of the lower animals. On the whole man turns out to be relatively insensitive to odors. This is especially true of those of us who live on the North Atlantic seaboard and who have a condition of mild chronic nasal catarrh. Certainly, anyone with even a minimum of olfactory sensitivity can detect and identify the odor of a characteristic perfume used by some one who has been in a room a few minutes previously. But once in a while one finds an individual who can come into a room and tell you each of a half dozen familiar people who have been in it during the last several minutes. This is because every individual has a characteristic bodily odor,—most of them are described as pleasant and are placed in the spicy or fruity classification—which can be detected and recognized by the individual highly sensitive to odors, but which pass unnoticed by the most of us. The author once knew an individual who was able to sort the wash of his family by smell alone even though the articles had been laundered in a common wash tub and even though the individual body odors had been masked by the use of a common laundry soap.

This high degree of olfactory sensitivity in man may seem incredible until we compare it with the even greater sensitivity to odors exhibited by some of the lower animals. Many tales about the ability of hunting dogs to track an odor seem like "long stories" but probably most of them are true. Certainly a well trained hunting dog will follow an olfactory track many minutes old with high speed and with great accuracy, even though it be over bare ground and with the wind blowing. And if another track, made by the same species of animal which the dog is following, crosses the first, he may hesitate a moment and sniff at each, but invariably he will proceed along the track he was following. Possibly he gets his cues from differences in the strength or intensity of the two odors or from certain characteristic qualitative differences. Just one more example to illustrate extreme olfactory sensitivity in the lower animals will be given. It is well known in deer hunting that the hunter should approach the animal with the wind blowing from the animal toward him rather than from the hunter toward the deer. If the wind blows from the man toward his quarry the deer will detect the characteristic human odor, at a distance very considerably greater than the man could possibly smell the deer, and will run away.

QUESTIONS

1. Why are tastes and smells so frequently confused?
2. What is the adequate stimulus for taste? What is the end organ? What different taste qualities are there? How are their end organs distributed on the tongue?
3. What two sorts of taste mixtures are recognized? What use is made of the fact of taste mixure?
4. What is meant by taste adaptation? By taste-blindness?
5. What is the adequate stimulus for smell? What is the end organ? What different smell qualities are there?
6. How do the facts of smell mixture compare with the facts of taste mixture?
7. What are the facts of adaptation to odors?
8. What biological differences exist with respect to olfactory sensitivity?

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CHAPTER IX

CUTANEOUS, ORGANIC AND STATIC SENSATIONS

Touch was included by Aristotle as one of his five sensory modalities. As examples of experiences in the sense of touch he included such things as hard and soft, warm and cold, rough and smooth. We shall see that some of these experiences are simple and that others are exceedingly complex. Little progress was made in the analysis of these experiences from the time of Aristotle until a relatively short time ago.

Some fifty years ago it was discovered that the skin was not uniformly sensitive to all kinds of stimulation. It was found that if a small enough stimulus was employed, the different kinds of sensations would be obtained only from definite and isolated spots. These forms of sensation are described as *cutaneous* inasmuch as they are all due to stimulation of the skin. The analysis has shown that there are five modalities of sensation which have their origin in skin stimulation. Each of these will be treated separately.

Contact is the first of the cutaneous modalities to be considered. The stimulus for contact is some object lightly touching the skin. There are at least two sorts of end organs for contact depending on whether or not the stimulation is of a hairy or a hairless part of the body surface. Only the end organ for the hairy parts of the body is definitely known. In the diagram (fig. 53) is an enlarged simplified drawing of a hair emerging from the skin with its bulb below the surface. It will be seen that the hair bulb under the surface of the skin is surrounded by nerve fibers. These nerve fibers are believed to be the end organs for contact on the hairy surfaces of the body. It will be noticed that the hair issues from the skin surface at an angle. If one will shave the hairs from any hairy portion of the skin and explore this surface by very lightly touching the skin with the end of a horse hair held vertically to the surface, he will find that it is possible to place the horse hair very lightly against the skin in many places without feeling it at all. This will be true only if the stimulation is so slight that the surface of the skin will be only slightly depressed. If you make a map of the position of the hairs and then make a second map of the places where the light horse hair contacts are felt, it will be seen that there is a relationship between the two maps. Light contact will be felt only in isolated spots to the "windward" of each hair. Inspection of the chart above will indicate that the place where this contact sensation is aroused, as indicated by the arrow as the place of stimulation, is directly over the position of the hair bulb. It is possible to arouse a contact sensation by any means which will change the relation of the hair bulb and the surrounding nerve fibers. If you will take a single hair emerging from the skin and touch it without actually touching the skin itself, or if you take hold of this hair and pull it from the surface of the skin, a contact sensation will be felt. The fibers surrounding the hair bulb thus seem clearly to be the end organ for contact

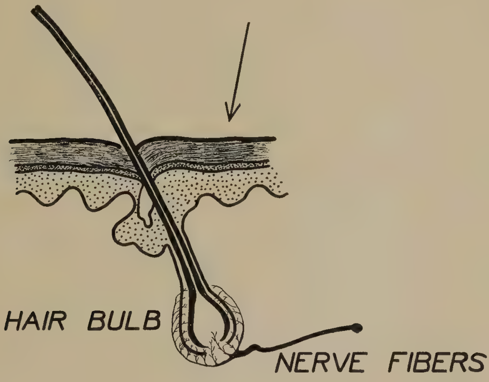

Fig. 53

for the hairy parts of the body. No one has yet discovered the end organ for contact for the hairless parts of the body such as the palms of the hands, soles of the feet, the lips and cornea of the eyes. Certain specialized end organs have been suggested as the contact end organs of the various hairless parts of the body but there does not as yet exist the clear cut experimental evidence on which an authoritative statement can be made.

We do know, however, that the skin is not uniformly sensitive to contact. On the average, stimulation with a very small and very unintensive stimulus, such as the end of a horse hair or a human hair, will arouse a conscious experience of contact from about 25 places in each square centimeter of skin. But the number varies considerably for different parts of the body ranging from 6 to 7 contact spots per square centimeter in the relatively insensitive lower leg and upper arm; about 26 on the back, 135 on the ball of the thumb up to approximately 300 in each square centimeter on the scalp, which seems to be the part of the body in which the greatest number of touch spots are located.

There is a great deal of experimental evidence regarding the strength of stimulation necessary to arouse a conscious experience of contact. And there are a great many experimental results on the ability to recognize which part of the body has been touched. The concept of *local sign*, which has already been mentioned in the discussion of kinesthetic sensation, was first formulated after the examination of the skin for sensitivity.

If you will take a pair of dividers and open them only very slightly and press them very lightly on the skin, the subject will report the stimulation by a single object. If the points of the dividers are gradually separated more and more, the subject will finally report stimulation in two places. This indicates that two points on the skin have to be stimulated, in order to arouse sensory experiences sufficiently different qualitatively so that the local sign for each can be noticed as different from the other and a judgment of dual impression reported. If you now keep one point of the dividers in the same place and determine in various directions from this point the amount of separation necessary to arouse two sensations with the large enough differences in local sign to be reported as two stimulations, you will find that the area so described will be circular or elliptical in shape. These have been called the *sensory circles,* although they are usually more truly ellipses. This elliptical form is found particularly on the elongated parts of the body, such as the arms and legs, with the long axis of the sensory ellipse running the long direction of the bodily part. One exception to the circular form of these is for bodily parts where there is a sharp anatomical break, such as the lines in the palm of the hand. If one point of dividers is placed just to one side of one of the important lines in the palm of the hand, it will be found that the form of the sensory circle will actually be a semicircle. The circular part will be away from the line but a very much smaller separation of the points of the dividers in the other direction will be necessary so that two points, one just on each side of the line, will give a great enough difference in local sign to be the basis for a judgment of two stimulations.

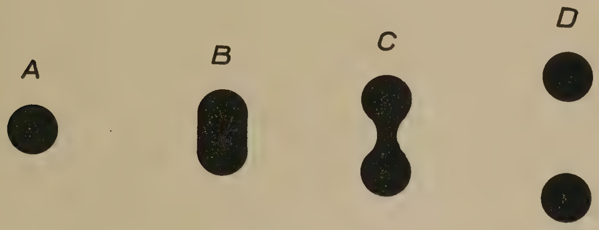

FIG. 54

The fact of the local sign for contact may be demonstrated by the following illusion. Consider the forefinger and the middle finger of the left hand. It is obvious that the right side of the forefinger and the left side of the middle finger will have different local signs because they are not only on different digits but they are separated by the width of the two fingers. If the fingers are crossed, these two surfaces will be brought opposite one another. Cross the fingers, and with the eyes closed, rub a pencil between the crossed surfaces. It will seem as if there were two objects, one stimulating each surface. This illusion is caused by the different local signs from the two surfaces which normally, in the uncrossed positions, are so situated that they cannot be stimulated by a single object.

In this connection we may return to a discussion of the problem of meaning which has already been mentioned in regard to the more complex visual processes, and see something of its effect upon judgments of single or dual impression from cutaneous stimulation. It has been observed that if the divider points are slowly opened and the skin successively stimulated by the different separations, one will have experiences which are described as resembling the fingers as shown in figure 54 in order from left to right. At first the experience will be like *A* of one point only. Then it will appear as an elongated single impression like *B*. If the dividers are still further opened it will appear like *C* as a single dumbbell-shaped impression. And finally one comes to a clearly differentiated dual impression of two stimulations. So far as process and meaning are concerned the impressions *A* and *D* are clearly the same,—each is respectively of one point or two points in either case. It is with regard to the *B* and *C* impressions that process and meaning vary. For process both of these impressions are clearly of one point while for meaning we know that a single impression of these shapes must have been made, in the experimental situation, by a two-point stimulation. If impressions *B* and *C* are reported as process, as a single impression, the sensitivity of the subject will be relatively very much poorer (the sensory circles will be larger) than if they are reported, on the meaning cues, as two points. In the first case the points of the dividers must be more widely separated than in the second for the first report of dual impression. It is these differences between process and meaning which make certain sorts of quantitative experimental work in psychology very difficult. These differences also account to a certain extent for differences in quantitative experimental results.

The size of the sensory circles varies very much for different parts of the body depending apparently upon the number and density of the sense organs in the skin. Thus the sensory circles are relatively large on the insensitive back and relatively small for the relatively sensitive finger tips. The form of a stimulating object may be perceived by contact if it is big enough to stimulate the skin outside of the size of a sensory circle. It has been determined that the perception of form by contact alone is usually relatively inaccurate. One of the best examples of the perception of form by contact alone and one of the best examples of the limits to which this may be accurately trained, is to be found in the reading of Braille type by the blind. Such type consists of groups of raised points in the paper differing for each letter or symbol in number and arrangement. These are felt, letter by letter, by the finger tips of the blind reader. Such reading by the blind may be very rapid and very accurate. But it is accomplished by the finger tips, which are among those parts of the body most sensitive to cutaneous stimulation. In spite of this, it is only accomplished because the figures to be differentiated are relatively large. Braille type is almost a centimeter in height, and for some symbols, almost the same width. In other words, it is necessary to print each Braille letter as large as the average little finger nail; as tall as the letters of good-sized type used for headlines in a paper, before its form may be accurately perceived by contact alone by one of the most sensitive parts of the skin.

There are no phenomena in contact which correspond to contrast, to the after-image, or to the abnormal condition of color blindness. Sensory adaptation to touch, however, is universally recognized. Normally we are not aware of the pressure of our clothes which are continuously stimulating the end organs of the skin. Part of this is due undoubtedly to the fact that we do not attend to these experiences but certainly some of the effect is due to sensory adaptation.

Up to this point in the discussion of cutaneous contact we have talked of a very light stimulation of the skin, so light that the surface of the skin would not be depressed. If the intensity of the stimulation be increased so that the skin is depressed and tissues, such as muscle and the like, are stimulated as well, we have a blend of contact and muscle sensation which has been called the *pressure* experience. Actually, in normal life, most stimuli do depress the skin, and our usual experience is one of pressure rather than of contact proper. The pressure blend can be recognized as being qualitatively different from contact. The subject is slightly more accurate in his pressure judgments than in those of contact alone and therefore he shows better sensitivity for pressure than for contact sensitivity.

Another modality of sensation elicited by stimulation of the skin is that of *cold*. The stimulus is normally contact with an object between the temperatures of 12° to 33°C. The sense organ for cold is not known although there has been a great deal of experimental work in seeking it. It has been found that the surface of the skin is by no means uniformly sensitive to cold. If you will take a thin nail or some other sharp metal object and cool it to 20°C. and then very lightly and slowly move it to explore the surface of the skin, you will find that in most places there will be only the experience of contact without any experience of temperature. As you move the stimulus slowly over the surface of the skin from time to time you will have an experience of cold which will vanish as the stimulus passes beyond this isolated point of the skin. One can thus make a map of the position of the cold spots on the skin, and having identified their position, it is possible to come back another time and obtain cold sensations by restimulating them. The position of the cold spots on the skin can be demonstrated to remain constant.

On the average, it has been found that there are approximately 13 small spots sensitive to cold in each square centimeter on the entire surface of the body. The number varies considerably from one part of the body to another, the back being again relatively insensitive with only 1 or 2 spots while the upper lip is extremely sensitive with approximately 19 cold spots in each square centimeter. A number of specialized end organs exist in the skin and a number of these nerve endings have been suggested as the end organs for cold for reasons of their position in the skin and the frequency with which they have been found. But several experiments which have been devised to determine the specific end organs for this cutaneous modality have all given negative results. In some cases the investigators have determined the position of especially clear cut cold spots on the skin and have cut out the skin beneath and around them for microscopic examination. Other experiments have involved the making of a map of all of the cold spots on a rather extended portion of the skin. This has been followed by the removal of the entire area and its microscopic examination in order to make a map of all of the different kinds of nerve endings in the skin of this area. In spite of a number of such careful studies no one has ever found any relationship between the cold spots on the surface of the skin and any particular specialized end organ in the skin beneath.

Warm sensations are elicited by contact stimulation normally with a range of 33° to 45°C. If one explores the skin slowly and lightly with a small nail heated to 38° to 40°C., it will be found that in only relatively few spots will any temperature experience be aroused. As the stimulus is slowly moved over the surface of the skin, one has the experience of contact alone, with only now and then the added temperature sensation of warm being felt. On the average it has been found that there are only 2 warm spots in each square centimeter of the skin. The number varies again for different parts of the body. No special end organ in the skin has been identified with assurance for warm in spite of several careful experimental attempts similar to those for determining the cold end organ.

One can be sure that warm and cold sensations each have their own special end organs although these have not as yet been identified. But experimental examination has demonstrated that both forms of sensitivity are very definitely localized in the skin in spots from which only one particular modality of sensation may be elicited and it has further been demonstrated that the spot for either form of sensitivity does not change its position. In both cases the warm and cold sensations have a local sign by means of which the localization of the part of the body stimulated may be recognized.

Adaptation to both warm and cold is very rapid and may be very complete. Continued stimulation of either will soon make that given intensity of stimulation ineffective. For example, if one goes into a room which seems at first slightly chilly and remains there a short time, the temperature sensations of cold will completely disappear and the room may seem comfortably warm. There is a certain amount of evidence that there is some general adaptation to cold during the winter months and to warm during the summer months.

Because of this temperature adaptation, it has been found that continued exposure of a part of the skin to a temperature of 11°C. and then followed by a temperature stimulation of 12°C. will cause this second stimulation, which normally is in the range of cold stimuli, to give rise to a sensation of warmth. One can easily convince oneself of temperature adaptation and the subsequent temperature contrast by the following simple experiment. Prepare three bowls of water. In the first have quite cold water, in the second have lukewarm water and in the third have quite warm water. Place one hand in the cold and the other hand in the hot water for several minutes until adaptation has taken place and the skin of the two hands has been prepared for the subsequent contrast. Then plunge both hands into the same bowl of luke warm water. To the hand which is adapted to cold the luke warm water will feel very warm while, to the hand adapted to warm, the same lukewarm water will seem cold.

There is still another form of temperature sensation called *hot*, the stimulus for which is a contact of an object with a temperature of more than 45°C. The belief is that we are here dealing with a cutaneous blend for which there is no special sense organ. Sensations of hot can never be obtained with a small stimulus which can stimulate a single end organ in isolation. Hot is certainly not intensive warm as it is usually considered to be popularly. If you find a warm spot in the skin, you can stimulate it with an object with as high a temperature as you please and the temperature sensations aroused will only be those of warm.

Sensations of hot can be obtained only by stimulating an area of the skin large enough to contain at least one cold and one warm spot. It has been discovered that a cold spot may be stimulated not only with the normal temperatures of 12° to 33°C. but also by a small stimulus with temperatures higher than 45°C. If an isolated cold spot is stimulated by the hot stimulus the conscious experience will still be that of cold. This phenomenon has been called *paradoxical cold.* Inasmuch as the experience of hot always affects an area of the skin large enough to include at least a cold and a warm spot, it is believed that this hot sensation is a blend of warm plus paradoxical cold from adjacent nerve endings.

This analysis of the basis for experiences of hot can be demonstrated by apparatus called the *heat grill* which is shown in figure 55. Two tanks are arranged: one with cold water at 25°C. and one with warm water at 40°C. A copper tube leads from each tank and these are wound around a grasping rod so that there are alternately tubes from the warm and the cold water tanks. The hand of the subject grasps the tubes wound over the rod at *A*. There is no connection whatsoever between the tubes through which flows the water from the warm and cold tanks. First the warm water is turned on alone. The tubes will definitely feel warm. After a time the cold water is also turned on and the sensation aroused in the grasping hand by the dual simultaneous stimulation of warm and cold will be found to be that of hot. So far as experience is concerned the conscious sensations have changed from warm to hot by turning on the cold water and by the actual lowering of the average temperature of the grasping surface. But the warm tubes stimulate the warm spots and the cold tubes stimulate adjacent cold spots. Hence this simultaneous stimulation of adjacent cold and warm spots gives the blend of the third temperature sensation of hot.

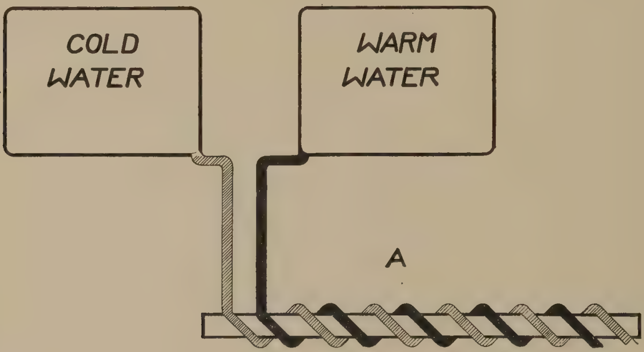

FIG. 55

Still another sensation aroused from the stimulation of the skin is *pain*. It has been found that these pain sensations are aroused only by intensive stimulation of any of the kinds of stimuli effective for cutaneous sensitivity. Hence intensive contact or pressure will arouse pain sensations. Or the experience of pain may be aroused by intensive warm or intensive cold stimulation. The end organs for pain seem to be the free nerve endings found very plentifully distributed through practically the entire skin. But still it can be demonstrated that the pain spots are punctiform like those for contact or the temperature senses. With a very fine needle it is possible to find places in the skin where it may be driven in between nerve endings and thus without arousing a pain experience. There are many more pain spots than those of the other cutaneous modalities. The tip of the nose is relatively insensitive with a density of only some 45 pain spots in each square centimeter. The inner point of the knee is highly sensitive with about 230 pain spots per square centimeter. There is a place in the center of the cheek which seems to be insensible to pain. It is this place which is utilized by the Indian fakir who runs pins through his cheek into his mouth. Indeed, if the pin be properly sharpened, it is not particularly painful to run a pin through the skin of the chest or elsewhere in the body. The skin is lifted from the muscle below. One feels pain as the pin enters the skin on one side and again as it comes out of the skin on the other side. The trick looks very effective but the pain is really no worse than that of sticking oneself with an ordinary pin. Pain localization is no more exact than that of contact and its localization is dependent upon qualitative differences of local sign. But frequently one finds it difficult to indicate just which tooth it is which aches. The sensory adaptation to pain is less rapid and less complete than it is for contact or the temperature senses. There is no evidence of a pain after-image or of any abnormal condition similar to color blindness or tonal islands.

Contrary to popular belief all pain experiences are qualitatively similar. The difference between a shooting pain and a dull ache is really not a qualitative one but is due to the pattern and the temporal course of the pain experience. For the dull ache the same intensity of pain continues for a relatively long time without change. The shooting pain, on the other hand, is one in which the intensity of the pain changes rapidly from time to time. For a time there will be relatively small intensity to the pain experience and then it will rapidly and suddenly increase in intensity.

In summary then there are five distinct cutaneous modalities of sensation included in what had previously been considered touch. The skin must be regarded as a mosaic of sense organs with some sort of special nerve cells,—as yet mostly not distinguished or isolated,—underlying the experiences of contact, pain, warm and cold. Each of these experiences may be aroused by a fine or punctiform stimulation of a very small spot on the skin. Hot, on the other hand, is obtained only when an area of the skin is stimulated which is large enough to include at least both a warm and a cold spot. Pain is obtained only from intensive stimulation of any of the other end organs. The relation between the stimulus ranges is illustrated in figure 56. At any temperature an experience of contact will be obtained so that contact may be considered as extending along the entire temperature range. Certain critical temperatures of stimulus under normal conditions are found above the horizontal line. The forms of sensory experience between these critical temperatures are found below the horizontal line. In the center of the line at 33°C. is what has been called the skin temperature or *physiological zero*. Stimulation by an object of this temperature will arouse a contact sensation only and no experience of temperature. Stimulations with

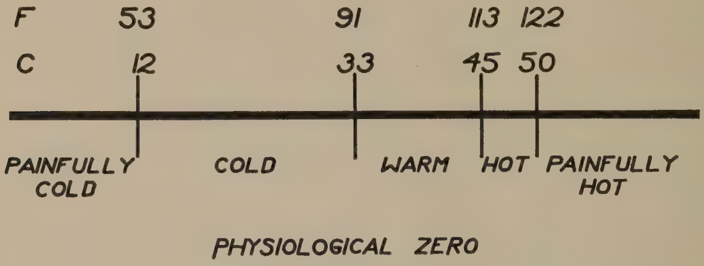

Fig. 56

lower temperatures will arouse sensations of cold,—simple cold down to approximately 12°C. and painfully cold from the more intensive stimulation below this temperature. In the other direction, sensations of warm are aroused above the physiological zero up to 45°C. At this point, paradoxical cold is elicited from the cold spots which combines with the experiences of warm from the warm spots to cause a blend called hot. This hot experience continues up to approximately 50°C. above which point, when the more intensive stimulation for pain enters to give the experience of painfully hot. Fahrenheit temperatures are added in parentheses for convenience.

Already we have seen the possibility of many touch blends, such as warm and paradoxical cold to give hot; contact or cold or hot blend with pain which give painful pressure, painful cold or painful hot. We certainly have blends of contact and pain with either of the two temperature experiences. The matter is even more complicated by blending with these already blended cutaneous experiences groups of kinesthetic sensations. Blends such as these account for the more complex perceptions, usually attributed to touch alone, such as those of rough and smooth, hard and soft. It is true that one may judge rough and smooth without movement although this is usually present in normal experience. Rough is usually an irregular intensity contact on the skin moved over a surface while smooth is a contact of constant intensity when the part of the skin is moved across a surface of a stimulus object. True, if the surface of the skin stimulated be large enough such movement need not be necessary. Then rough is a simultaneous stimulation of different intensities on parts of the skin widely enough separated so that each has a different local sign; while the experience of smooth may be analyzed into a constant intensity of stimulation on all parts of the skin stimulated.

But it does not seem possible to obtain the experience of hard and soft without come contribution from kinesthetic sensation to the complex blend. Thus if the skin is in contact with a stimulus and one finds that the intensity of the contact experience increases as the skin is moved toward the object, the perception is described as one of hard. Soft, on the other hand, is the complex perceptual experience of movement toward an object with which the skin is in contact without any considerable increase in the intensity of the contact sensations.

The perceptual experience of wet is a blend of the two cutaneous qualities of contact and cold. If the kinesthetic element is added giving the complex blended experience of contact and kinesthesis to make soft to which cold is added, one may describe the perception as clamminess. If a perfectly dry rubber balloon is filled with cold water and lightly touched to the skin of the blindfolded subject, the blend of contact plus cold will give the blended sensory cues so that he will judge it to be wet. If the subject is then allowed to hold the bag and squeeze it, giving the blend of kinesthesis plus contact without much increase in the intensity of the contact (which gives the experience of soft) plus again the sensation of cold, he will describe the perfectly dry object as clammy. Many such perceptual experiences have been analyzed and they all prove to be blends of the various modalities of cutaneous sensations to which, in many cases, are added the kinesthetic sensations arising from movements of the various parts of the body.

Until now we have spoken only of the sensations and perceptual experiences aroused by stimulation of the surface of the skin of the body. From inside the body itself are aroused the forms of sensation which are called *organic*. One usually thinks of these organic sensations in terms of such experiences as hunger, thirst, nausea and the like. The psychologists and many surgeons disagree regarding the sensitivity of the internal organs. The surgeon will tell you that, although the body wall and the diaphragm are extremely sensitive, he can cut and cauterize any of the internal organs without evidence of sensibility. Probably this is because the sensitivity of these internal organs is temporarily effected by the shock of the operation.

Some very careful studies have been made of the sensitivity of some of the internal organs by experimental methods. For example, it is possible to investigate all of the digestive tract,—the so-called alimentary canal,—except the small intestines. One can insert a rubber tube through the rectum and investigate the colon or the large intestine. One can swallow a rubber tube and investigate the sensitivity of the esophagus and the stomach. By marking different lengths on the tube and taking x-ray pictures of the tube in place in the body in these different positions, it is possible to determine just which parts of the digestive tract are being stimulated. It is possible to force water at different known temperatures through the tube; to force through certain chemicals as stimuli. One can increase the pressure inside any of these organs of the alimentary canal in the following ingenious manner. A rubber balloon is tied to one end of the rubber tube and this is then sucked back up the tube. This end is then swallowed until it is in position, let us say, at the top of the stomach. A pump is then inserted into the other end of the tube and the balloon is blown out and inflated in the stomach. A pressure gauge in the system of tubes indicates the amount of pressure in the balloon and the intensity of the pressure against the inner wall of the stomach.

Stimulation in these various ways indicates that all of the parts of the alimentary canal are sensitive to exactly the same sorts of stimuli as the surface of the body. The esophagus, stomach and the colon prove to be sensitive to pressure, pain, cold, warm and hot to almost the same degree as the surface of the skin. One encounters in this work some curious errors of localization regarding the place stimulated. Thus pain sensations having their origin in the esophagus are described as pains in the forehead just above the eyes. Hence the usual so-called "ice cream pains" in the forehead are due to a painfully cold sensation in the esophagus. The chart above regarding the critical temperatures and stimulus ranges for cold, warm, hot and painfully cold and hot of cutaneous sensations are almost as correct for the true organic sensations aroused by stimulation of the internal organs.

Those experiences which are popularly thought of as organic sensations, such as hunger and thirst, turn out to be complex and are really blends of two or more of the five simple sensations obtained from stimulation of the internal organs, in a particular combination pattern with a particular bodily localization and in a particular temporal pattern. Thus hunger turns out to be a blend of sensations of pressure and pain localized in the stomach in a temporal pattern of rhythmic increase and decrease of intensity. Thirst is largely a blend of pressures and warmth localized in the throat without much change in intensity over a relatively long time and frequently with the addition of a constantly relatively non-intensive pain. The call to urination is largely a combination of pressures and warmth with sometimes pain over a localization in the lower abdomen in the region of the bladder with a temporal pattern of very slow rhythmic changes in intensity. Other organic sensations

FIG. 57

such as nausea, the call to defecation and some of the sexual experiences all turn out to be complex blends of the fundamental five cutaneous and organic qualities of pressure, cold, warm, hot and pain with different localization and in different temporal patterns.

We finally come to a relatively simple but extremely important modality of sensation which has been called *static* modality. It is this which gives us cues regarding the position of our body in space; whether we are lying down or standing up; whether we are standing erect or standing on our heads. The stimulus for static sensation is a change in the position of our body with regard to the center of gravity of the earth. The sense organs are called the *semicircular canals* and they are found one set on each side of the head in the inner ear closely associated with the cochlea. On each side of the head there are three connected tubular holes in the arrangement depicted in figure 57.

All three tubes are connected with each other and the entire system is filled with a liquid which presses against nerve cells lining the internal parts of the tubes. The tubes are arranged each in one of the three planes of space. Tube *A* runs directly backward and forward. If the head is tilted forward the pressure of the liquid is increased in the forward part of this tube and decreased in the rear of this tube. The canal marked *B* curves outward toward the outside of the head. Thus if the head is tilted to the right, the pressure of the liquid will be increased in this tube in the right hand system of semi-circular canals and decreased in the same canal in the left hand system. The canal marked *C* curves directly upward toward the top of the head. If one stands upright the liquid tends to drain out of this canal to decrease the pressure while, if one stands on his head, the pressure will be increased in these third canals. The sensations of going downward in a rapidly moving elevator are due to the inertia of the liquid increasing the pressure in this upright canal marked *C*. Any change in the position of the body as a whole or of the position of the head will thus change the relative pressures of the liquid in two or more of these semi-circular canals and the resultant static sensations become the basis of our knowledge of the position of our body in space.

Frequently the cues from the semi-circular canals alone are inexact and incorrect. This is particularly true in the presence of increased or decreased atmospheric pressure in the ears which effects both the hearing parts and the static parts of the inner ear. Individuals have had the experience of making a deep dive with the consequent increase of pressure and not knowing which direction to the surface of the water was correct until they opened their eyes and obtained the cue of differences in illumination. Aviators of a few years ago told of the experience in "blind flying" at night, in the clouds, or in a fog, of suddenly discovering that they were flying upside down. This was of such frequent occurrence that a device has been added to the instrument boards of airplanes which indicates the position of the plane, and of the aviator, in space. The importance of the effective operation of the semi-circular canals and of the static sensations obtained from them has been recognized for aviation. Hence one of the first tests which a candidate for aviation must pass is to demonstrate at least a minimum standard of static sensitivity. It is because of the close relation of the semi-circular canals and the other structures of the ear that all aviation candidates are at once rejected if there is any evidence of former ear disease or of a burst or punctured tympanic membrane.

If one is placed in a revolving chair with the eyes bandaged, and swung about in the chair, one becomes aware of the beginning of movement and any change in the speed after the movement has started. But, if all secondary cues are removed such as the air against the face, one is not aware of movement at a constant speed. One is again aware of static sensations, however, when the movement is stopped. It is only starting, stopping or change in the rate of movement which is the effective stimulus for static sensation. This form of conscious experience is dependent upon the inertia of the liquid increasing and decreasing the pressures in the different parts of the system of canals. After continued motion at a constant speed and in a constant direction for a time, the liquid will be moving at the same rate as the canals themselves and hence these pressures will be equalized. In this situation of equalized pressures there will not be any static sensations and the perception of movement may be experienced only by secondary cues. It is interesting to note that the continued stimulation of the semicircular canals from the movement of a ship in rough water is certainly one of the main contributing causes of seasickness.

When a movement of the body has been continued in a given direction for some time and is then stopped, the liquid, which acquired the same momentum as the bones of the skull, continues to move in this same direction and thus increases the pressure in one end of the canal. This causes a negative after-image of movement in the opposite direction from the original movement. Most children have played the game of spinning about several times in one direction with the eyes closed and then stopping suddenly. They seem to be then spinning in the opposite direction. Let us suppose that the canal pictured in figure 58 is the horizontal canal on the left side of the head. This individual spins to the right as indicated by the direction of the arrow. The inertia of the liquid forces it back to the rear end of this canal and thus increases the pressure at the back. After continued movement in this direction for some time, the liquid acquires the same momentum as the surrounding bones and membranes of the canal. When the movement is stopped, however, the momentum of the liquid will force it to pile up in the front end of this canal, increasing the pressure here. But increased pressure in the front of the horizontal canal is the normal sensory cue for movement in the opposite direction and is as a consequence the basis of the normal negative after-images for the static modality.

The specificity of each of the particular canals for movements in its particular plane may be demonstrated by the following simple experiment. Place a subject in a revolving chair or a piano stool with the eyes bandaged. Have him place his head over as far as possible on the right shoulder. This position of the head will bring the normally vertical canals into a horizontal position. With the head held in this position rapidly spin the subject around to the right a number of times with as great rapidity as possible. This will back up the liquid in the vertical canals,—now in a horizontal position,—exactly as if the subject was doing a rapid series of backward somersaults. Then suddenly stop the rotation and have the subject at once straighten his head to the normal position. The momentum of the liquid will increase the pressures in the other ends of the vertical canals giving rise to an after-image of movement in the other direction. The blindfolded subject will have the experience, with the head in the erect position, of apparently falling over forward and he may actually fall over backward to compensate for this impression unless he is caught and held in an upright position.

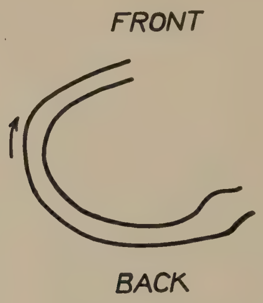

Fig. 58

A few words of summary of the discussions of the sensory and perceptual processes which have been treated in the last several chapters seems worth giving here. We have discovered a situation exceedingly complex and much more complicated than that envisaged by the earlier psychologists. Besides the modalities of vision, audition, taste and smell, we find that the modality of touch of Aristotle is really a complex of five modalities,—pressure, pain, cold, warm and hot. Besides these there are also the important sensory modalities of the kinesthetic and static sensations and of the organic sensations. This makes a total of twelve modalities of sensation in all which the modern psychologist must consider as compared to the list of only five recognized by the psychologists up to little more than a hundred years ago. For each of these twelve modalities, we have considered the adequate stimulus, the sense organs so far as they have been identified, in some cases the range of stimulus, the number of totally different sensations and the number of perceptibly or noticeably different experiences. Complete data from experiments on all of these points could not be given because of lack of space, in some cases, and in others because the experimental data do not exist at present. What we have tried to emphasize throughout these discussions is that for each modality there are simple sensations, and also complex experiences which are the result of blends of several simple experiences within a given modality or of blends of sensory experiences from each of several modalities. Also to these blends of simple sensory experience is added the contribution of meaning. The experiences of seeing, hearing, smelling, touching and the like turn out to be truly complex in normal life but they are perfectly capable of being analyzed into the simpler elements of which they are composed.

QUESTIONS

1. What are the varieties of cutaneous experience? On what grounds are they distinguished?
2. What is meant by local sign? Why is this concept necessary?
3. What various end organs are believed to be concerned in cutaneous experience?
4. What are sensory circles?
5. How does hot (as a sensation) differ from warm, cold, touch, pressure and pain? On what experiments does this distinction rest?

6. Is there any difference between the sensitivity of the internal as compared with the external surfaces of the body?
7. What are the organic sensations?
8. What is the end organ for static sensation? How does it work?
9. How are aviators examined for disorders of static sensation?
10. What are the most important facts that one should know about the sense modalities?

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Chapter X

THE CONDITIONS OF CLEARNESS

In the last chapters we have considered many phases of sensory and perceptual experience. The stimulus conditions for differences in quality have been particularly stressed. It has been pointed out that the difference between red and yellow is based upon differences of vibration frequencies of the stimulus, for example. In some cases the bases and conditions of other factors have been treated, for example, the dependence of the intensity of auditory experience upon the amplitude of the sound waves. In the present chapter, our concern is with the clearness of mental processes and with the conditions for differences in clearness.

Glance at figure 59. You will see the portrait of a man, Richard Wagner. This you will probably see with great clearness. If you will examine this picture, however, you will discover that it is composed of a large number of small figures representing characters from the works of this composer. If you will examine your conscious processes as you now look at this picture you will discover that one figure after another is in consciousness with great clearness and that all of the other figures recede less clearly into the background. But, meanwhile, what of the picture as a whole which, you will remember, was your first clear perception before you noticed that it was composed of smaller figures? All the while you are examining all of the smaller figures, the total portrait of the composer has certainly receded to a less clear position in consciousness. From your own observation there can be no doubt of the fact that there exist differences in the degrees of clearness with which different processes may be simultaneously in consciousness. Only a relatively small part of consciousness is clear,

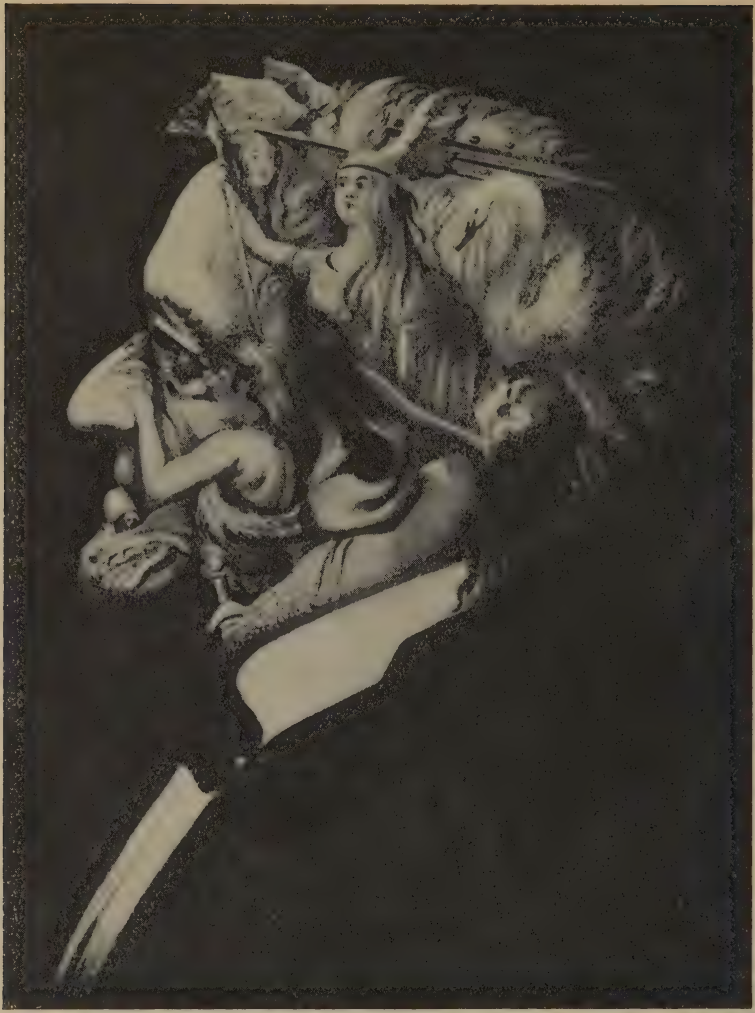

Fig. 59

while the rest of consciousness forms a relatively less clear background.

It is the nature of the conditions on which these clearness differences are based which will be treated in this chapter.

This is really, then a chapter on what has been called *attention*, but we have hesitated to use the word until we could define it in the light of modern psychological thought. Popularly, attention is thought of as a sort of mental searchlight. It is popularly believed that when you wish to attend to something you turn this searchlight on it. And it is believed that the difference between a person with a "good" power of attention and a person with a "poor" one is in the ability to hold this searchlight steady and without wavering on the particular object of your choice.

Nothing could be further from the truth than this popular concept. One may retain the word attention only if one is willing to use it as describing the clear part of consciousness in contrast to the parts less clear. And it must be recognized as well, that there are just as understandable conditions for these differences in clearness as there are for differences in quality or intensity or any other characteristic of our conscious experiences. Indeed the field of consciousness may be likened in some respects to the field of vision with the single eye. The illustration (fig. 60) might represent either the monocular visual field or the field of consciousness. If it were the field of vision we know that *A* would fall upon the fovea of the retina, and would thus be clearer than *B*, *C*, or *D*, all of which are off the

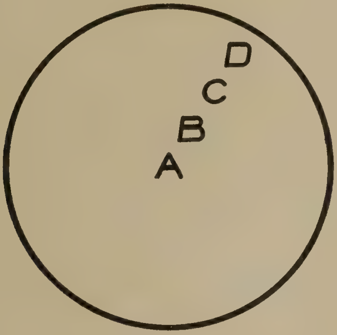

FIG. 60

fovea. We know this because we know that the fovea is the part of the retina which makes for distinct and clear vision. If this figure represented the field of consciousness at any moment of time, again *A* would represent the part of the field clear in attention while *B*, *C*, and *D* would represent parts which are less clear.

However, there is this important difference between the figure taken as representing the field of vision or as the field of consciousness. In both cases we have seen that *A* in the center of the fields would be clearer than anything else in the field.

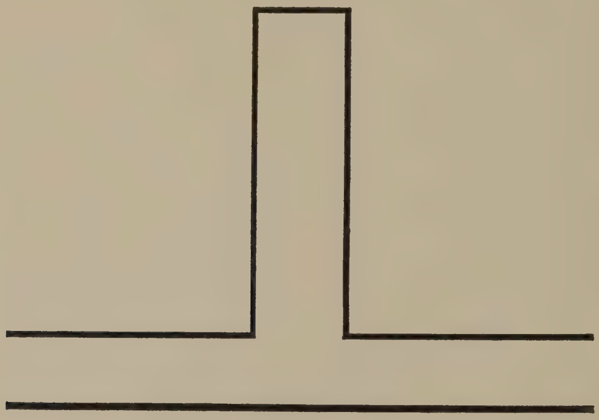

Fig. 61

But if the figure represented the field of vision, we have experimental results which show that there is a gradually decreasing degree of distinctness as one goes from the fovea to the periphery of the retina. Thus, for vision, *B* would be more distinct than *C* and *C* would in turn be more distinct than *D*. For attention in the field of consciousness, on the other hand, experimental results indicate that all mental experiences not in the center of attention form a background of equal clearness. Hence for attention, and differing from the case in vision, *B*, *C*, and *D* would all be of an equal degree of clearness, forming a less clear background for *A* which would be in the center of attention. Thus, attention involves only two levels of clearness,—there is first a clear level experienced against second, a relatively unclear background all parts of which have the same relative degree of unclearness. These relations may be illustrated by figure 61 in which the lower horizontal line represents the *threshold of consciousness.* Everything below this line is not conscious. Everything above this line is in the conscious field. The part above the conscious threshold is divided into a high portion, which represents the clear center of consciousness, surrounded by the low parts of less, but of the same degrees of, clearness.

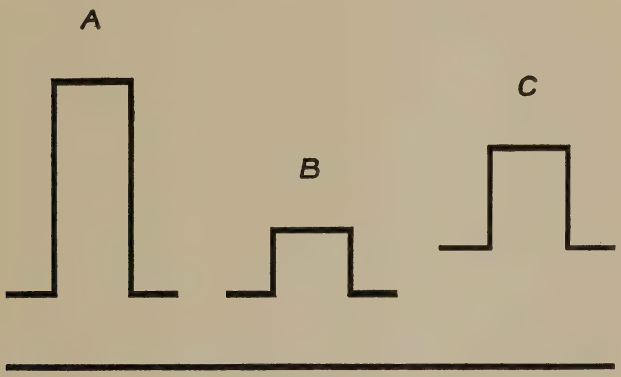

Fig. 62

If one studies the characteristic differences of the degree of clearness in consciousness of a number of individuals or of one's own consciousness from time to time, a number of different characteristics become evident. In the first place there may be a difference in the relative height of the two levels of clearness. These differences may be illustrated in figure 62 which is merely a modification of the relations already explained in figure 61. The three parts of this figure represent the clearness relations of the field of consciousness at three different times. *A* represents what might be called very concentrated attention on a part of the field. *B* represents relative inattention such as we might have during day dreaming, while *C* represents a rather high degree of attention not particularly concentrated upon any part of the field. Thus in the concentrated attention, in *A*, a small part of the field is exceptionally clear while the rest of the field is exceedingly unclear. In the day dreaming, represented by *B*, there is again not much relative difference between the clear and the unclear parts, but both are relatively clearer than in *C*. It may be stated as a law that the clearer the central part of the field, the greater the clearness difference between this and the unclear background.

The figure *B* which we have just described as representing the clearness relations during day dreaming certainly occurs from time to time in all normal persons. But it is also the constant characteristic of the clearness relations in the consciousness of certain feebleminded individuals. For them, no part of the field of consciousness ever reaches a degree of clearness great enough, so that it may stand out from the less clear background. This constant lack of clearness of any part of the field may go a long way toward giving psychological account for the feebleminded condition. At the other end, one might represent a figure in which the central clear portion of consciousness was so high that the background of the unclear part of the field sinks almost to, or in some cases, actually to the level of the conscious threshold. This would be a schematic picture of certain types of insanity and the clear central portion of consciousness may become what has been called a *compulsive idea* forcing the individual to make a certain reaction. The successful normal individual, then, is one in whom the conscious field may be represented by two levels of clearness very widely but not too widely separated from one another. It is obvious that these clearness differences enable an individual to particularize one part of the conscious field from the rest.

Another characteristic difference in the two clearness levels is what has been called the *range of attention*. This has to do with the number of stimulus objects of which one may be clearly conscious at any one moment of time, and may be represented by the breadth of the upper and clearer part of the conscious field. There is an old game which consists of covering a number of small coins or pebbles with the hand and then exposing them by rapidly raising the hand for a moment and asking the number of objects exposed. It will be found that the number correctly reported will be relatively small,—usually, not more than from five to seven objects. Differences in the range of attention may be illustrated by figure 63 in which both figures *A* and *B* show, by the height of the lines an equal degree of clearness and of clearness differences. But in *A* there is a relatively broad line representing the clearer portion of consciousness, indicating a large range of attention while in *B*, this part of the figure is narrow representing a poor range of attention.

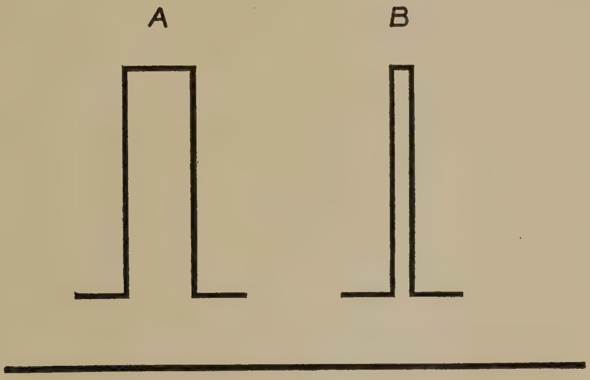

FIG. 63

Experimentation in the field of the range of attention has been difficult for two reasons. In the first place one has to decide on a definition of a stimulus object. If one exposes a number of individual letters for a tenth of a second, which is too short a time for movement of the eyes, it will be discovered that five to seven are all that may be seen with a degree of clearness great enough to reproduce them immediately or to even report the number of letters exposed. But if a number of familiar three letter words are exposed for a similar length of time, it is found that as many words may be reported as were single letters in the former exposure. This would look, at first, as if one increased one's range of attention threefold by exposing letters in words rather than letters alone. Such is not the case because there is other evidence which indicates that words are perceived on the basis of their total form and not as groups of letters. Hence in the first exposure the letter is the individual stimulus-object; while in the second exposure, the word is the stimulus-object. Thus in both cases the range of attention is the same.

Another difficulty with this form of experimenting is the difficulty of having the observer confine his observation to the actual time of exposure. It is possible for most subjects, after the exposure is completed, to call up a memory of his short perceptual experience and to actually change clearness relations in this memory so that he is able to count the number of stimulus-objects which must have been present. By this means, the range of attention will be apparently but not actually increased by this subsequent changing of the clearness relations of the field in memory. This fact falsified the measurement of the range of attention because what is really meant by the term is the number of objects clearly in consciousness at any *one* moment of time.

There is a story that Napoleon was able simultaneously to listen to a report read to him, to dictate some other material and to read still different material. To perform all of these three operations at the same time would indicate a range of attention so far beyond the normal as to be totally unbelievable. Probably the story is untrue, like many others which grow up about heroic figures. But if Napoleon was able to accomplish this feat, it was probably not on the basis of a tremendously wide range of attention, but rather on the basis of an ability to shift the objects in the clear center of consciousness very rapidly.

If you are interested in having information about your own range of attention look at figure 64A but only after you have read the instructions and have prepared for the experiment. On page 160 you will find the numbers from 1 to 50 arranged in a haphazard order. Number 1 will be found in the upper left hand corner of the page. You should have exactly 40 seconds in which to do the test. Arrange for a signal after which turn the page. Presumably you will see this material for the first time. With a pencil draw a line from 1 to 2; from 2 to 3 and so on consecutively until time is called at the end of the forty seconds. The last number you have reached within the time limit is your score. Standards on this test have been worked out for college students. Some very few college students are able to complete the joining of the entire 50 numbers within the forty second time allowance, the first time they have seen the chart. Such individuals obviously have a very wide range of visual attention. They are able to look at number 1 and have a clear part of the conscious field which is broad enough to permit them also to perceive the number 2. They have no need to hunt for number 2 by moving the eyes over the figure until 2 comes into their narrow field of attention. Naturally this takes more time than if the conscious field was large. The average score of individuals in college is in the range of the high 20's.

Some years ago one of the greatest broken field runners in the history of football was examined in a psychological laboratory to discover what characteristics would account for his outstanding performance on the football field. It was discovered that he had remarkable talent in three directions. In the first place he had one of the widest ranges of attention of which there is a record. This meant that, in any football play, he would look down the field and clearly see all of his teammates

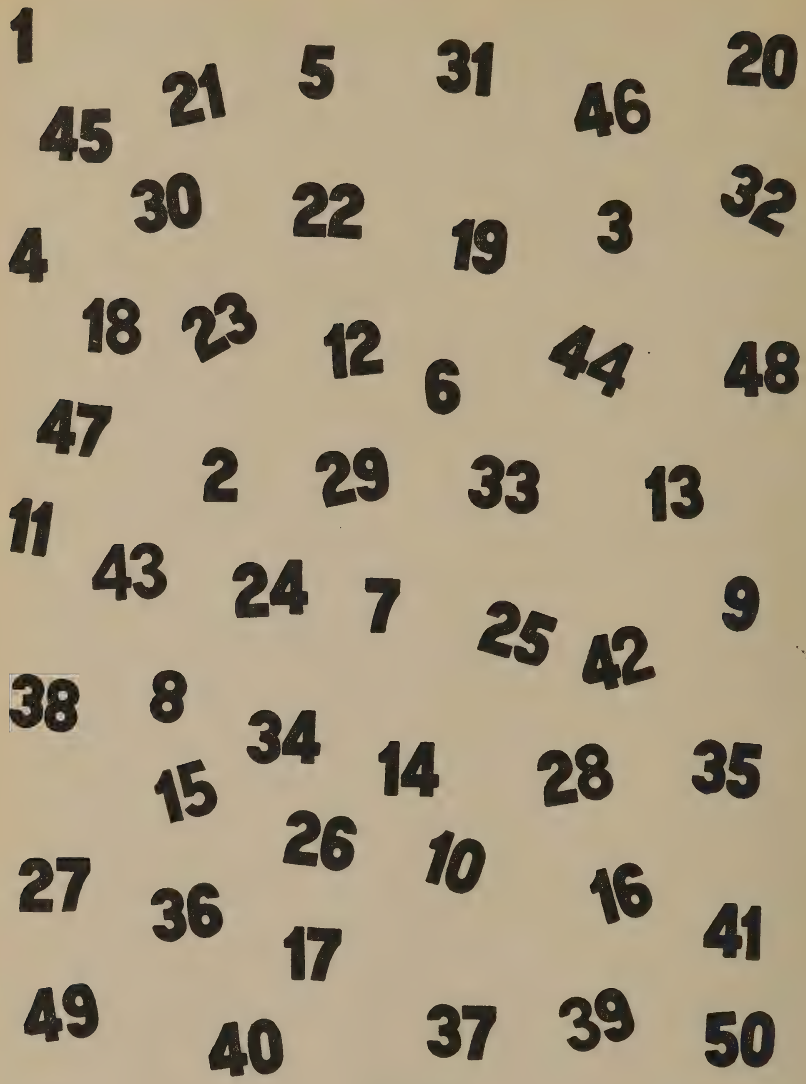

Fig. 64A

and his opponents—their position and the direction and speed with which they were running. He was able to perceive clearly the entire pattern of the arrangement of players in a single grasp of consciousness. On the basis of this single flash of clear consciousness of the entire field, he could determine where he himself had best run. Secondly this individual proved to have an ability to make movements very rapidly. He could change the direction and the pace of his running instantaneously. Thirdly, he was born with such large, strong leg tendons that these were not injured by the rapid change of direction and pace. Strong leg tendons, a very rapid time of reaction and a very large and wide range of attention combined to make this individual one of the greatest open field runners of all time.

Another characteristic of attentional clearness is what has been called *persistence*. This is measured by the length of time during which a single object can be maintained in the clear field of consciousness. Turn again to figure 59, the portrait with the hidden figures. Select any single feature and try and hold it indefinitely as the clearest part of consciousness. You will soon find that it loses in clearness and that other features of the figure will intrude themselves into the clear center of consciousness. It has been found that the persistence of attention to a very simple stimulus-object is measured in seconds or even fractions of a second rather than in longer intervals of time. Of course, if the stimulus-object is complex it would be possible to keep it longer in the center of attention, but this would be accomplished only by bringing first one part and then another into clearness. For example, you will say that you are able to attend to the reading of a book for hours at a time. But in this case you are dealing with a very complex situation in which the clear center of consciousness is constantly changing as your reading proceeds from phrase to phrase.

You can prove to yourself the short time that you are able to hold any stimulus-object clearly in the center of consciousness by looking at a particular star on a clear night. You will find that the star "twinkles." This twinkling really consists of losses of clearness with a high degree of clearness again recovered. This is because the star is an unintensive visual stimulus which must be seen with maximum clearness if it is to be seen at all. You will also observe that a relatively unintensive star twinkles more frequently than a more intensive one. It is possible to reproduce this stimulation in the laboratory with the following very simple experiment, in order to prove that the effect is due to lack of indefinite persistence of attention rather than to atmospheric conditions, as is so frequently believed. Make a light proof box with a light in it and with black cardboard in one side. Make a pin hole in the cardboard to represent an artificial star. Then, in a totally dark room, move the box away from the observer until the artificial star can just be seen. If you continue to observe this artificial star for a period of time, you will discover that it will disappear and reappear and that it cannot be held in clear consciousness for a length of time of more than several seconds.

The picture in the comic papers of a college professor is always one in which his so-called "absent-mindedness" is an outstanding characteristic. This absent-mindedness gets him into all sorts of trouble—he walks into a lake without seeing it; he is hit by an automobile and the like. But is the absent-minded professor really absent-minded? By no means. His trouble is that he has too much presistence of attention, and that such great persistence is usually accompanied by a narrowing of the range of clearness. His trouble is that he is thinking of his problem with such persistence, as he walks along, that his attentional range is narrowed and the lake into which he steps or the automobile which hits him never gets into the clear field of consciousness at all.

The fourth characteristic of attention is what may be called alertness. This is measured by the rapidity with which a number of stimulus-objects may successively enter the field of clear consciousness. From one point of view, the test of drawing lines from the numbers 1 to 50 on page 160, in some cases might be considered a test of alertness as well as of range of attention. It is possible that there are some few individuals with a very poor range of attention but great alertness who could make a fairly good score on this test because the alertness or great rapidity of successive change of the stimulus-objects in the center of conscious clearness would somewhat compensate for the narrow attentional range.

The individual who is successful in life is as a rule one who has a balance of these four characteristics—the degree of clearness, the range of clearness, the persistence of clearness and alertness to changes in clearness. There are situations in life in which each of these characteristics of attention is useful. In reading some difficult passage in a book, persistence is required. In conducting a symphony orchestra, an extremely wide range of attention is required. Without this wide clear consciousness, it would be impossible for the orchestra conductor to hear and control the tempo and the quality and intensity of the sounds made by each of the individual members of his orchestra.

Indeed one can say that no individual could become a successful orchestra conductor without an exceptionally wide attentional range. Fortunate is the individual who has an excellent development of all of these characteristics, but especially fortunate is the individual who, with these abilities, is able to apply the appropriate characteristic to the proper situation. Real success in life may depend on the applying of persistence at the expense of range in one appropriate situation, and on applying range at the expense of persistence in some other appropriate situation. The example of the "absent-minded professor" illustrates the employment of too much of a valuable characteristic of attention in an inappropriate situation.

One aspect of the attentional characteristics is that there are wide individual differences for each of them. These differences seem to be *congenital* in basis. Congenital means *born with.*

It does not necessarily mean inherited although at times a characteristic may be both inherited and congenital. Thus color blindness is both congenital and inherited. One is born with this condition and it is passed on to an individual through his mother by a color blind grandfather. Whether the congenital aspect of the attentional characteristics is also inherited is an open question on which the data for a decisive answer do not exist at present.

When we say that a narrow or a broad range of attention is congenital we do not mean that there cannot be improvement in this characteristic during one's lifetime. Indeed the normal course of individual development from birth to adulthood is one of improvement in all of these characteristics. What is implied by congenital is that the *limits* of development of any of these characteristics are fixed at birth and that no amount of training and practice will develop the characteristic beyond these fixed limits. In one sense, then, it may be said that an orchestra conductor is born as far as attention is concerned. At least, to develop into an orchestra conductor, the individual must have been born with wide enough limits of his range of attention to be adequate, through training and development, to this particular situation. Usually but not always, the congenital limits of any of these characteristics may be determined relatively early in life. The man who exhibits great persistence or a wide range of attention would have probably exhibited the same characteristics as a child as compared with the standards for that age. This is not always true. Frequently neither the child nor the man approaches the possible limits of development set at birth. How seldom do any of us actually develop any characteristic to its possible limits of development!

It is a universal observation that attention always involves muscular adjustment. Kinesthetic complexes are always the earmark of attention. This is obviously true, from your own experience, in narrowed and persistent attention, and it is equally, although perhaps less obviously, true for all attention.

In the first place this kinesthetic complex accompanying attention is partly a matter of muscular adjustment of the sense organs for clear perception. It will be remembered that the essential fact of attention is that of clearness. Take the case of vision, for example. Clearness for vision requires the accurate focusing of the image of a stimulus-object upon the fovea of each eye. But it will be remembered that such focusing involves the coördinating of the lines of sight by the contraction of some of the external muscles of the eyes so that the image may fall within both of the retinas. Also is involved the contraction of the muscles controlling the shape of the lens and the size of the pupil in each eye. The establishing of maximal clearness of the retinal images of an object visually perceived, involves then a complex of contractions of at least three different sets of muscles in each eye. Rather less obvious but equally true are the muscular adjustments for clear attention to experiences from other modalities of sensation. Attention to a relatively unintensive sound almost always is accompanied by a turning of the head to bring the more sensitive ear—and for most people one ear is more sensitive than the other—toward the source of sound.

Besides these complexes of muscular contraction of the sense organs or of muscles to make the action of the sense organs more effective, attention is usually accompanied by a number of involuntary muscular adjustments. During difficult attention, at least, there is a tendency for the breathing to be both shallower and slower and there is a tendency for the heart beat to become slightly slower. This is almost always accompanied by a partial contraction of the muscles of the abdomen.

Throughout this chapter, we have spoken almost entirely of the attentional clearness of sensory or perceptual experiences. The facts we have mentioned are equally applicable to the bringing into clearness of a memory image, or successively, of parts of a complex memory image. The degree of clearness, range, persistence and alertness characteristics, are as important for attention to a memory image as they are for perceptual experiences. And it has been found that muscular adjustments are just as prevalent when an image is being brought clearly into consciousness as they are in perceptual attention to an external stimulus-object. Thus one not only discovers the contractions of abdominal muscles, the changes of heart beat and breathing accompanying the clear imaging of some past experience in memory, but also frequently there are muscular contractions involving the effective adjustments of the appropriate end organ as well. Thus in recalling a visual memory to maximal clearness in consciousness, the eyelids are frequently shut and the eyes themselves are rolled upward and sometimes inward. In recalling an auditory memory experience to maximal clearness, the head is frequently turned or tilted so that the more sensitive ear is brought to what, for the perception of an actual stimulus, would be an especially effective position. Indeed the kinesthetic complexes of muscular contractions of adjustment are so universally an earmark of attention, that some psychologists have insisted that attention is really nothing more than this pattern of muscular adjustments necessary for making the sense organ most effective and thus making the sense experience maximally clear. This might be accepted as true were it not for the facts of attention in the field of the consciousness of memory images where there is no external stimulus, and therefore, where sense organ adjustment seems unnecessary. Indeed, it is possible to bring a visual memory to maximal clearness in consciousness after an operation by which both eyeballs have been removed so that the muscular adjustments of the sense organs are impossible in this case.

It has been found that there are certain external and internal conditions which facilitate the bringing of the representation of a certain stimulus object or of an idea into the clear center of consciousness. Each year, when lecturing on attention, I do the following demonstration to illustrate this point. After having said something in the lecture which seems important enough to be put into the notes which the students are taking, I wait until practically all of their heads are down and they are busily writing in the note book and then I give a loud and sudden shout. As if all of the heads belonged to a single body, they all come up and look in the direction of the shout. It is then possible to point out to the students that a moment before the shout the material of the lecture was in the clear center of consciousness, but that, with the intrusion of a sudden, intensive stimulus, these ideas either dropped out of consciousness all together or at least dropped to the lower levels of clearness and that the sudden and intensive experience has usurped the position of maximal clearness. A sudden and intensive stimulus is one of the conditions particularly effective for attentional clearness.

It has been found also that a moving stimulus, particularly in a stationary field, is highly effective in claiming the center of conscious clearness. Any hunter will tell you how difficult it is to see an animal as long as it remains still, but how clearly the same animal, which had not been perceived before, is clearly perceived once he begins to move. The greater effectiveness of a moving stimulus for clear attention is equally true in other sense fields besides vision. It has been found, for example, that the sensory circles obtained for the movement of a single point on the skin are smaller than that for two points stimulating the skin simultaneously and without movement.

We have found that such external conditions as a sudden, intensive or a moving stimulus are particularly effective for bringing some stimulus object into maximal conscious clearness. Certain other conditions which have to do with the apperceptive background of the observing individual—and may therefore be described as internal conditions—seem also to be highly effective in this respect. Thus a novel experience, new to one's apperceptive background, seems to stand in the center of consciousness with an almost dominant clearness and usually with relatively great persistence. Similarly the general principle of *congruity* seems to be highly effective for bringing an idea or a stimulus object into the clear center of consciousness. The principle of congruity is that of a new conscious experience fitting into the background of previous conscious experiences or of conscious interests. If one happens to be interested in dachshunds, every dog of this breed which is seen will immediately come clearly into the center of consciousness while dogs of other breeds may not even be noticed at all. It is safe to say that you have noticed no mention of a Persian cat or of an octogenarian for some time in the daily newspapers. But if one should become interested in either, so that this idea established a conscious congruity, you may be sure that you will notice their frequent mention in the daily papers. If either idea was congruous with the background of apperceptive consciousness or with one's interests, he would find that every mention of it, in the daily newspapers, would immediately intrude clearly into the center of consciousness.

Attentional clearness which has its basis in such external conditions as suddenness, intensity or movement of an external stimulus or in such internal conditions as the novelty or congruity of a sensation or an idea with the other contents of consciousness, has been called *involuntary attention.* It has been called involuntary because the individual seems to have nothing to do with this particular idea or experience claiming maximal clearness. This seems to be determined either by the nature of the stimulus itself or by the nature of the general state of consciousness and of the ideas and interests present in consciousness at any particular moment. Contrasted with this there is what some psychologists have called *voluntary* or *voluntarily initiated* attention.

This is a situation which always involves conflict,—one in which two or more sensations or ideas are competing against each other for maximal clearness. It is the popular belief that an individual may, by his will, call either one of these competing experiences into the clear center of consciousness and push the other into the unclear background. This is certainly not the true description of the course of events. But what actually happens in this situation will more properly be discussed under the topic of the so-called voluntary types of reaction in a later chapter.

Under this topic of conflict for the clearness center of consciousness, however, we may briefly treat the general problem of distractions. A distraction is merely some sort of conscious experience, incongruous with the train of ideas of the moment, which tends to displace in clearness some congruous conscious experience. The distraction may be basicly a perceptual experience with an external stimulus, such as a band playing under your window when you are trying to study, or it may be an idea without immediate external stimulus, such as the idea of going to a moving picture which comes into consciousness, while you are working out a problem in mathematics.

Some years ago an ingenious investigator worked out a method by which he hoped to measure the strength of attentional concentration or persistence. He used a number of mental problems of equal degree of difficulty to be performed by the subjects. He discovered experimentally, for a number of observers, their standards for doing this type of problem without distractions as measured in terms of the times necessary for completion and of the number of errors. Once having determined the standards for normal, undistracted work, he proposed to introduce distractions of various intensities and measure the degree of persistence of attention in terms of the loss of work efficiency resulting from the distractions.

The interesting result which he obtained was that the efficiency of the work was actually increased and not decreased in the presence of a mild and unintensive distraction. One may actually do better work and have congruous ideas more clearly in consciousness in the presence of a mild distraction, such as a band playing under one's window, provided that they do not play too loudly. If the distraction is increased enough in intensity, however, one always comes to the point where the work efficiency is decreased whether it be measured in terms of speed or in terms of number of errors.

Some more recent work was verified these results of greater work and attentional efficiency when a mild distraction is introduced. But it has been shown, by these recent experiments, that this increased efficiency is purchased at the expense of a much more than normal expenditure of energy as determined by such physiological measures as the amount of oxygen used by the body over a given period of time. What apparently happens is that normally we do not use our maximal ability for attention. In the presence of a mild distraction, we attempt to maintain our normal level of efficiency by a more complete attentional adjustment. In this we over shoot the mark, we make a more complete attentional adjustment than is needed to maintain the normal level of efficiency, so that there is an actual gain in the work record. But such a better adjustment involves many muscular contractions and other bodily changes which use up more than the normal amount of energy as measured by the rate of oxygen consumption. As the intensity of the distraction is increased one comes to a point when further adjustment is not possible no matter what the degree of expenditure of energy and from then on the distraction makes itself felt by decreasing the efficiency of the work as the distraction increases in intensity.

We have seen then that there is nothing mystical about attention. It is not to be considered as a sort of mental searchlight which may be turned at will on this or that conscious process to bring it into the foreground of consciousness. Attention is not to be considered as a faculty or an ability which has the power of bringing some part of the conscious field to the foreground at one moment and pushing it into the background at another moment. All we mean by the term attention is the fact that the different processes in consciousness may vary in relative clearness—some may be relatively clear and all of the others form a background of the same degree of relative unclearness. It has been found that these clearness relations between the contents of consciousness may vary in four ways: (1) in the relative degrees of clearness between the center and background; (2) in the range or the number of experiences which may be clearly in consciousness at any one time; (3) in the persistence or length of time which any clear part of consciousness may be kept in maximal clearness and (4) in the alertness or rapidity with which the processes in the clearness center may change. All of this requires muscular adjustment to the point that kinesthetic complexes are one of the earmarks of attention. And finally, we have seen that these clearness relations between the constituents of a conscious pattern at any moment of time are dependent upon a number of external conditions of stimulation and of a number of internal conditions within the consciousness of the observer.

QUESTIONS

1. In what way may the field of vision and the field of consciousness be compared? In what way do they differ?
2. In what way is attention related to feeblemindedness and insanity?
3. What is meant by the range of attention?
4. How may your range of attention be apparently lengthened?
5. How may the range of attention be investigated?
6. How is it possible to maintain attention on a book for hours at a time when it is so difficult to persist in attention to a single stimulus for short intervals of time?
7. How can absent-mindedness be explained?
8. What four characteristics of attention are of importance in life situations?
9. In what way is attention related to kinaesthetic sensation?

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PART III. THE COMPLEX CONSCIOUS PROCESSES

Chapter XI

MEMORY IMAGES

In the last seven chapters we have treated the immediate conscious effects of the stimulation of one or another of the various sense organs. This discussion has brought to light twelve different modalities of sensory experience. In each of these situations consciousness occurs only upon the stimulation of a sense organ by some stimulus object outside the central nervous system. It will be remembered that the stimulus need not necessarily be outside the body—for example, in the cases of kinesthetic and organic sensitivity.

There are abundant experimental results which indicate that consciousness does not begin immediately upon the stimulation of the sense organ. There is a definite measurable *latent time* between the beginning of stimulation and the beginning of consciousness of that stimulation. And there are abundant experimental results which indicate that there is a lag, again a latent time, between the termination of stimulation and the termination of the conscious process. It has been found that these latent times vary for different modalities, but in every case, they are measured only by small fractions of a second.

For all practical purposes, since these latent times are so short, we may say that the conscious sensation or perception ceases with the termination of the stimulation of the sense organ. Certainly, the lag of the small fraction of a second of the consciousness, after the removal of the stimulus, is unimportant from a practical viewpoint. Try to imagine, then, the mental condition of an individual who was completely and adequately endowed with all modalities of sensory experience but with nothing else. Such an individual could see, hear, feel, and have all of the remaining experiences as well as any perfectly normal person. Such an individual, for example, could see all of the letters and words on this page, but these would be merely black marks on a white background to him. Each letter and word would be a new experience every time that he saw it. For this individual with sensation and nothing else reading would be impossible. Even disregarding the question of the meaning of words, it would not be possible for this individual to read a sentence because, for this, it is necessary to hold in consciousness the first part of the sentence while one is reading the latter parts of the same sentence.

For this hypothetical individual, possessing sensation and nothing else, conscious life would consist merely of a series of discrete conscious experiences each lasting only during the actual period of stimulation of the sense organ, and then dropping out of consciousness forever, with the termination of stimulation. Such a mental life could be described as an "ever present now" in which there was no continuity of mental experience and in which each conscious moment would bear no relationship to what had gone before and what was to follow.

However, it is universal experience that one's mental life has continuity and one cannot overemphasize the importance of this conscious continuity. Such continuity of conscious experience requires some sort of a "hang-over" so that the consciousness resulting from the sensory stimulation of any moment may be related to the consciousnesses which went before. We have already described one simple form of this mental "hang-over" in the discussion of the after-image in the treatment of visual and static sensitivity. Here we have found that there may be a *subsequent* as well as an *immediate* effect of the stimulation of a sense organ. It has been found that there may be a conscious experience following the withdrawal of the stimulation, but which has its basis in this same previous stimulation. This sensory after-image, which is the simplest sort of conscious after experience following the stimulation of a sense organ, is really of little practical importance as the basis of mental continuity, however. The true *memory image* is much more important in this respect.

But there are certain points of similarity between the sensory after-image and the memory image which it seems worth while to point out. In the first place both have their origin in some form of previous stimulation. Since psychologists have discarded the notion of innate ideas, they have universally insisted that the memory image was entirely dependent upon some previous stimulation. It is not possible to call up in consciousness a memory image of an experience which one has not had sometime before. For example, it is not possible for a color blind person to call up an image of what red looks like because he has never had the sensory experience of this color. For emphasis we repeat that both the sensory after-image and the memory image come to consciousness after the original stimulus has been removed,—both are conscious hang-overs resulting from previous stimulation. In both cases there is a latent time between the termination of the sensory experience and the beginning of the after experience in consciousness. In the case of the sensory after-image, this latent time is short,—it may be measured in a few seconds at most. But in the case of the memory image, the latent period may be days or weeks or years in length. Between the termination of stimulation and the appearance of the memory image in consciousness long periods of time may elapse. For example, you may recall an experience today which has happened to you a long time ago even though that experience has not been in consciousness in the meantime.

How is one to account for this memory image which comes to consciousness? One very widely accepted explanation, which is still rather widely believed, involves the dividing of mind into two parts. This explanation says that only a small part of mind is conscious and that below this is the great *subconscious mind.* One believer in this theory has likened mind to an iceberg of which the conscious mind is the small one-tenth above the surface of the water and the subconscious mind corresponds to the great submerged nine-tenths. Such a theory says that every conscious sensory experience creates an image which remains in mind during the entire lifetime of the experiencing individual. But most of the time these ideas are in the subconscious part of the mind. They only come into the conscious part of mind when they are recalled. Ideas or images are thus conceived as maintaining their existence in the subconscious. On the basis of this sort of theory it is easy to lapse into the ridiculous. It is easy to conceive of the subconscious mind as a series of card catalogue files in which the ideas are stored on separate cards. Then the efficient mind would be one in which the filing had been carefully accomplished in the subconscious so that one could easily pull the correct idea from the file at any time, and bring it up into consciousness. Unfortunately this theory of the basis for the memory images seems unsatisfactory, incorrect and unnecessary to most psychologists. For example, there seems to be no possible anatomical basis for a subconscious mind in the central nervous system or elsewhere in the body.

It is an accepted principle in psychology that wherever possible we should relate psychological processes with basic physiological processes. Wherever possible we must explain consciousness in terms of the functioning of the nervous system. Naturally, then, we must turn to an explanation of the memory image in terms of the physiology of the nervous system. Again there seems to be a parallel between the sensory after-image and the memory image. The sensory after-image is based upon a change in the sense organ due to the stimulation. The light stimulating the retina of the eye changes the composition of the photochemical substances in the retina and it is this change in the nerve cells of the end organ which is the basis of the after-image. At present no one really knows exactly the nature of this physiological change in the eye although there are a number of theories to account for it. Similarly we may believe that the stimulation of a number of brain cells so modifies them, in a way as yet unknown, so that a restimulation of these cells is again accompanied by a memory image of the previous stimulation in consciousness. If this modification of brain cells takes place, it is of a much more permanent character than the modification in the sense organ.

It will be necessary to wait for further developments in the physiology of the nervous system to know just what actually happens by way of modification of brain cells. But of the following one may be sure. Sensation or perception requires three factors: (1) brain (because the process is conscious and consciousness only occurs with neural activity of the brain); (2) a sense organ and (3) an external stimulus effecting the end organ at the time of consciousness. Eliminate any of these three factors and you have eliminated conscious perceptual experience. The after-image requires only two factors: (1) brain and (2) a sense organ modified by previous stimulation. And the memory image requires only one factor, namely, a brain, part of which has been modified by previous stimulation. We shall find shortly that if certain parts of the brain are destroyed certain memory images are lost. One is cautioned, however, not to think of this modification as taking place in a single nerve cell in the brain for each particular memory image. The situation is certainly much more complicated than this.

One may contrast the physiological explanation of memory with that calling upon the subconscious mind. If the notion of subconscious mind is used as explanation, then it is the memory image as such which has constant and permanent existence and which is only occasionally brought from the subconscious into the conscious mind. In the physiological explanation of memory, the image has only intermittent existence while it is in consciousness. The thing which is constant and permanent is a nervous system so modified that, if it is properly restimulated, one will have a similar but not the same idea or image in consciousness. This may be explained further by analogy. We have a candle and stimulate it with a match and obtain a flame. We then blow out this flame. What happens to the flame? It does not go back into the candle. Nothing of that sort happens. It ceases to exist, and that identical flame will never exist again. But we still have the candle so constituted that if it is restimulated with another match we shall obtain a similar flame. By analogy, we have a nervous system which we actuate with an external stimulus, and we have an idea in consciousness. We withdraw the stimulus and the consciousness ceases. What happens to the idea? It ceases to exist. But there is still the nervous system, modified by this previous stimulation, now so constituted in consequence, that if the modified brain area is restimulated, we shall obtain a similar idea in consciousness. Certainly most physiological and much if not all psychological evidence points toward an eventual explanation of the memory images in terms of modification of groups of brain cells by previous stimulation, and the notion of a subconscious mind thus becomes unnecessary, and had better be discarded entirely from psychological thinking.

There are as many varieties of memory images as there are modalities of sensory experience. Call up a memory picture of the interior of your room. You can probably see this mental picture with great clearness both as to form and color. This is called the *visual concrete image* because it is a visual memory of concrete objects. Now call up a visual memory of how the name of your institution would look either written or printed. This is called the *visual verbal image* because it is a visual memory of words. Some individuals find it more difficult to call up a visual verbal image than a visual concrete image. This distinction between a verbal and a concrete image may seem to be merely a logical one at the moment, but, we shall find when we come to the discussion of some of the abnormal aspects of memory, that there is a real psychological basis for the distinction.

Try to call up into consciousness various other sorts of memory images. You can call up an image of the sound of a train whistle (*auditory concrete image*) or one of the sound of the voice of some intimate friend (*auditory verbal image*). Without any actual movement of the muscles involved, you can call up a *kinesthetic concrete image* of how it would feel to throw a ball or a *kinesthetic verbal image* of how it would feel if you said the word "bubble." Similarly you can call up concrete images of experiences of the other sensory modalities, —of the taste of sugar or of the smell of a rose. Verbal images exist for the modalities of vision, audition and kinesthetic sensation only because it is only through these three modalities that one may have verbal experience. If you have tried to call up images of each of these modalities and all of the others as well, you may have noticed a number of facts. Again call up the olfactory image of the smell of a rose. You will discover that you are actually inhaling while you are trying to call up this memory image. In other words you are actually stimulating the olfactory end organs although not with the usual stimulus for this odor. But to pursue the investigation a little further, you will find that you can call up a visual image with your eyes shut which eliminates all such external stimulation. Try the following experiment which is different from the usual olfactory situation and which more or less corresponds to the closing of the eyelids for vision. Take a deep breath and exhale slowly and while you are exhaling try to call up an olfactory image of the smell of a rose. Many individuals, who are able to obtain this image while inhaling find it impossible or at least difficult to get it while they are exhaling. Again try and call up an image of the pain of hitting your thumb with a hammer. You may be able to do this, but certainly the pain image will not be as clear or as intensive as the actual pain experience. Certainly, the image is not of an intensity to make you dance about, nor will it lead to the other reactions which usually accompany intense pain.

There is plenty of introspective evidence that images of all sensory modalities may exist. But also there is evidence that the images of the three modalities of vision, audition and kinesthesis are more intensive, clearer, or of more frequent occurrence. Generally, they are much more important than those of the other kinds of sensory experience. In the interests of simplification, therefore, images of the visual, auditory and kinesthetic modalities will be treated further. And it will be remembered, one must consider both concrete and verbal images for each of these three modalities.

Most individuals find that there are differences in their ability to call up images of these three modalities. Some find that they have best control of the auditory or kinesthetic images, but most individuals report that their visual imagery is best. Try and spell a long word like "university" first forwards and then backwards. You will find that you can spell it forwards more rapidly than backwards. But if you had excellent visual verbal imagery, you should be able to project an image of this word against the closed eyelids and spell it with equal speed in either direction. On real examination, many people find that their visual imagery is not as good as they thought it was. There is an obvious reason for the apparent superiority of the visual image. This is because the visual image has a static character in consciousness which is not enjoyed by images of the other two modalities. One can hold a visual image in the mind's eye almost indefinitely. But most auditory images are representations of relatively short sounds in nature. Indeed it is curious how few sound stimuli have long constant duration. Hence the duration of the concrete auditory image is short because of the nature of the stimulus. This is certainly also true of the auditory verbal image because the speech stimulus is a very rapid succession of different sounds. The kinesthetic image is a representation of movement, which is in fact a perception of a bodily part successively in different positions in space, and hence the perception of no single position can remain long in consciousness again because of the nature of the stimulus. Certain habits of attention further militate against the static quality in consciousness of the kinesthetic verbal image. When we speak we tend to listen to the sound of our own voices rather than attend to the muscular feel of the movements necessary in pronouncing the words. This is so true that it has not been more than fifty years since the kinesthetic verbal image was first recognized and described in the psychological literature.

It is these relative differences in the static character of the visual image, as compared with either auditory or kinesthetic images, which give them this apparent prominence in consciousness. Indeed one can be sure that any person so far advanced educationally as to be reading this book has at least a reasonable ability in handling kinesthetic verbal imagery because no one without this ability could have progressed so far in our present educational system where so much stress is placed on material of this kind.

It seems worth while to here make the distinction between *imaginal endowment* and *imaginal type.* Imaginal endowment consists of all those kinds of images which one is able to call up and use. Great individual differences exist in this respect. One can determine one's own imaginal endowment quite readily by merely finding what sorts of images he is capable of calling up and what sorts he is unable to call into consciousness. Merely try to call up various concrete and verbal images of experiences in all of the sensory modalities and you may thus determine those sorts which form part of your endowment. Most, but not all, individuals will find that they are capable of calling into consciousness images of all of the modalities. There is evidence that one's imaginal endowment is to a large extent congenital. Some few individuals seem to be born lacking the ability to call up images of some particular modality and if this ability is entirely lacking, no amount of training seems able to effect any improvement.

Contrasted to imaginal endowment is *imaginal type* which consists of the sorts of images one uses with the greatest frequency. Obviously one's imaginal type is circumscribed by his endowment, inasmuch as he cannot use any sort of imagery frequently which he is not capable of calling up at all. Again it has been found that there are great individual differences in imaginal type. Most individuals have a mixed type in which several sorts of image are used with great frequency. The so-called pure type, in which one sort of imagery is used almost exclusively is very rare, but apparently exists in some individuals. There is great variation from one individual to another in the particular modalities of imagery which are combined to constitute a type. The most frequent combination seems to be the imaging of concrete experiences largely in visual terms and the recall of verbal experiences largely in terms of the kinesthetic verbal image. The determination of one's imaginal type is much more difficult than the determination of one's imaginal endowment. It may be accomplished only by a long series of introspections to determine what sorts of imagery one is using in many different situations in actual life. If this is done a large number of times in many different situations, one gradually develops a composite picture of the kinds of image used most frequently. We shall find that the knowledge of one's imaginal type, of one's special abilities and special defects, may be very valuable for determining the sort of activity which an individual may best enjoy in life.

To indicate the limits of ability in the handling of images of one sort or another we shall briefly describe the accomplishments of some individuals of exceptional imaginal endowment. There is the story of a very noted French actor who was able to go on the stage without notice and without preparation and correctly act the principal part in any one of a large number of plays. He was able to do this because his visual verbal images were so clear, so complete and accurate, as to be actually photographic. When called upon to substitute in a part without notice, he could call up an image of the pages of the book of the play so clearly that he could read his part from the visual verbal image as well as if the actual script was in front of him.

Some years ago the author discussed the imaginal processes of a certain well known artist who is recognized as a master in the field of landscape painting. This artist had been interested in his own imaginal processes and his methods of work. It was found that he had an unusual procedure for landscape painting. He does practically all of his painting in his studio in winter, although his specialty is summer and autumn landscapes. During the warm months of the year he tramps about a great deal with his notebook making hundreds of sketches which are so crude that they are almost meaningless to anyone else who looks at them. Then some winter morning he will arrive at his studio and he will feel like painting. The sketch-book is brought out and the pages turned until he finds a sketch which calls up a visual concrete image of a landscape which happens to interest him. The sketch is merely a jog to his visual concrete memory. He glances at the sketch, calls up a very exact concrete visual image of the actual scene clear in detail and color, and then the book is closed never again to be opened at this page. He then begins to change his visual image in the interests of composition and of color harmony. He changes the position of the house in his image, he changes the color of the barn, he puts in a cloud which was not in the original image and he eliminates a group of trees in the foreground. He does all of this with the image clearly before him and before he has touched his canvas. This artist begins to paint only when his concrete visual image exactly suits him, and he insists that his painting consists merely of overcoming certain technical difficulties so that his canvas may become as exactly as possible a reproduction of his image. This is a degree of the ability to use the concrete visual image much greater than that enjoyed by most of us.

In the field of the auditory image, one turns to the exceptional endowment of certain musicians. For example, there seems to be a well authenticated story of a very well known composer who, at the age of 14, went to the Sistine Chapel in Rome for a visit. Here he heard just once a lengthy composition written in a number of parts. It is reported that he went home and wrote all of the parts of the entire composition. The manuscript was shown to the choir master of the Sistine Chapel who was able to discover an error in only three notes, and who said that had the piece been performed as this youthful musician had written it that those errors would not have been noticed. This is a degree of ability in recalling auditory imagery quite beyond the comprehension of those of us who find difficulty in recalling a short theme song, which we have heard perhaps half a dozen times in an hour, as we are walking out of a moving picture theater.

One could give many other examples of exceptional endowment or ability to use images of one sort or another, but it seems more worth while to describe the consciousness of an individual who is totally lacking in imagery of a certain sort. It happens that the author is highly deficient in visual imagery. He cannot remember ever having had a visual verbal image of any sort whatsoever. Perhaps this is the reason why he is a notably bad speller. He can never remember calling up a visual concrete image in his waking life. Sometimes in dreams, there comes to consciousness what might be considered a rudimentary sort of visual concrete image but this is always vague, of short duration, without form and entirely colorless. The nearest that he ever approaches to a visual concrete image occurs very rarely in dreams when a dark formless gray spot may appear from which a voice seems to issue. This is really all so meaningless to him that he has to presume that this was a rudimentary visual concrete image of the person talking. The author has systematically tried for many years to train his ability to use the visual image but entirely without success. Indeed the rudimentary visual images in dreams are gradually becoming less frequent in occurrence. This defect of the lack of visual imagery has no basis whatsoever in defective vision. The author has excellent visual acuity, more than usual sensitivity to colors and very lively and persistent colored visual after-images. The defect has its basis not in the sense organ but in those parts of the brain which must necessarily be modified by experience to be the basis of the visual image.

Having described this case in some detail, it seems worth while to recount some personal history to indicate how such a defect may be a real handicap in many pursuits in life. Careful and continued introspection reveals a highly mixed imaginal type for this individual in which auditory concrete, kinesthetic concrete and kinesthetic verbal images are frequently used with much clearness and accuracy. It is those activities which more definitely require the visual image that give trouble. The author did not realize this defect until he was taking a course in psychology and here, for the first time, he realized that his memory processes were not like those of other individuals. The reciting of only one difficulty will suffice to the purpose here, but it was so serious that his college career was almost terminated at the end of the first semester of his freshman year. The difficulty was with solid geometry. Imagine doing solid geometry without an ability to visualize the figures. He had succeeded in passing through plane geometry with much labor, but he now realized it was with the help of a most curious and inefficient method. He learned the figures in terms of kinesthetic imagery by drawing them. But a kinesthetic recall of the figures could never be detailed enough to include the lettering. The solution of each problem was memorized literally in parrot fashion in kinesthetic verbal imagery. Many a time in recitation and in examinations, he has first drawn the figure from kinesthetic concrete memories, then written out the solution using kinesthetic verbal imagery and finally logically gone back and lettered the figure from a consideration of the written solution. But such a totally inadequate method of work, forced upon him by his defect of imagery, broke down for solid geometry because the figures are too complicated for this sort of procedure. He succeeded in passing the course only because the final examination consisted almost entirely of original problems which could be solved by the application of general principles and with little necessity to resort to detailed memories of any of the actual problems studied.

The author has presented himself in some detail as an example of an extreme defect. It has been pointed out that such a defect may be a real handicap. For example, he could never be a painter and he hopes that he will never be called as a witness to describe in detail some visual occurrence. It may also be reported that he is a very slow reader in a profession in which he must do a great deal of reading. This slowness of reading results from the fact that he cannot glance at a printed page and obtain the meaning by just seeing the words. It is necessary for him to say each word to himself subvocally as he reads and this method, of course, takes time and very considerably slows the speed of reading.

But there is a great deal of evidence which indicates a partial solution to this distressing state of affairs so that the effects of such a defect are partially lessened at least. It is universally known that an experience does not have to be recalled in the images of the same modality in which it was experienced. It is possible to recall speech which you have heard in terms of a visual verbal image. It is possible to recall words which you have read in kinesthetic verbal images. In other words, another modality may function as a substitute or "surrogate" for recall of the modality in which you have experienced an event. Thus, in the author's case, he finds it possible to recall many experiences resulting from visual stimulation sometimes in auditory concrete, but usually in kinesthetic concrete and verbal imagery. Were it not for the fact of this transformation from one modality to another, the author might almost as well be totally blind so far as recall of visual past experiences is concerned.

Finally it seems worth while to present a detailed description of the memory processes of an individual with a highly mixed type but also with very exceptional endowment in his ability to recall images of a number of modalities. Some years ago, the author was able to obtain a very detailed introspective description of the imaginal processes of a very well known orchestra conductor. It was found that this individual had an ability to recall visual images of thousands of pages of scores of orchestral compositions with truly photographic fidelity. In symphonic scores, each bar of music is numbered consecutively. He could tell you the notes played by each instrument for any bar in any of these hundreds of compositions, when you merely gave him the title of the composition and number of the bar, by simply reading them from his very exact visual image. Needless to say this conductor does not have a score before him during a performance of his orchestra. His visual image of the score is entirely sufficient. It was also found that he was able to read a new score, which he had never seen before, and to call up with this reading, a clear auditory image of how the music would sound if played,—what the sounds would be from each instrument in isolation or from all of the instruments playing together. There is evidence also that this individual is exceptional in the field of kinesthetic imagery. He has the ability to call up the exact motor images necessary to the accurate playing of a number of instruments, particularly the unfretted stringed instruments such as the violin. This orchestra conductor shows very marked imaginal endowment for all three of the important sensory modalities, —visual, auditory and kinesthetic,—and it seems certain that his success as a conductor and his eminence in the musical field is in part, and possibly in large part, due to the fact that he was fortunate enough to have been born with these marked abilities and that he has developed them to such a great extent.

We have spoken of the mental image as the basis of memory. What then happens to the memory image during the gradual process of forgetting? The popular belief is that the memory images grow fainter with each subsequent recall as time goes on until they finally disappear. Such a description might be illustrated somewhat as follows. The diagram (fig. 64) represents what is considered to happen to the image of a chair in subsequent recalls. The clear image to the left represents the first recall after learning and the successively less clear images at subsequent intervals of time are shown consecutively toward the right. Such an explanation would seem to fit admirably into the physiological explanation of the memory image on the basis of the modification of parts of the brain. It seems reasonable to conceive that this modification gradually disappears and that this gradual disappearance of the modification with time would be accompanied by a gradual fading of the intensity and clearness of the memory image in consciousness.

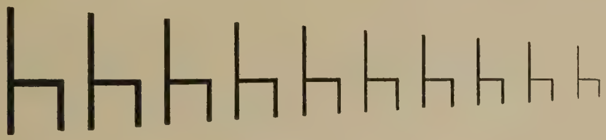

FIG. 64

However, there exist adequate experimental results which indicate that the course of the image in consciousness is quite different from this. It will be realized that ordinary complex experiences are recalled in consciousness as highly complex images, and for the normal person of mixed imaginal type, there are usually a number of images of several modalities in such a complex recall. These experimental results of the course of the memory image during forgetting may be illustrated by figure 65 in which the circle to the left represents a hypothetical complex image before any forgetting has taken place. The succeeding circles to the right each represents the changes which have occurred to this complex image after successive intervals of time and with different degrees of forgetting. The original image consists of a number of part images of the different modalities as represented in *1*. In all of these figures visual part images are represented by the letter *V*; auditory by *A* and kinesthetic part images by the letter *K*. In *2*, after some forgetting has taken place, it is found that some of these part images have been lost entirely while those that remain are as intensive and as clear as they ever were. Successively through *3*, *4*, and *5*, we have a picture of the gradual dropping out entirely of more and more of the part images but again those which remain are as intensive and as clear as they ever were in the first place. Normal forgetting may then be represented as a cone of which our circles are cross sections in time finally at *6* reaching a vanishing point at which all of the part images have disappeared and we may say that this memory is entirely forgotten. Normal forgetting of a complicated experience, then, consists of the dropping out completely of more and more of the part images of which the original memory was composed but with those part images which remain recurring in consciousness with their initial degree of clearness and intensity.

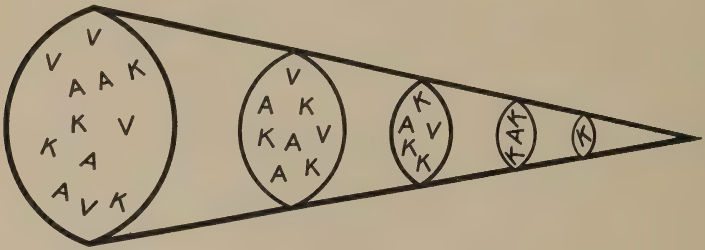

Fig. 65

Still another interesting fact came out of this investigation of the course of normal forgetting. It was discovered that no matter what the modality of sensation of the original experience or what the imaginal type of the observer, images of the different modalities seemed to drop out with different speeds. The visual image, although it is the most detailed, seems relatively to have a very short life and to drop out early while the kinesthetic image, although it lacks detail and is never more than an approximation in fidelity, relatively lasts an exceedingly long time. For example, we know that if one has ever been able to swim at any time in the past, he can go into the water and swim, after a long period of time, without loss of accuracy, although of course there may be loss of efficiency. In the diagram above we have tried to illustrate these facts of the differences in the rate of the dropping out of part images of the different modalities by having relatively a greater proportion of visual images in the earlier experiences and a relatively greater proportion of kinesthetic images in the later recalls after forgetting has been partially accomplished.

More light may be thrown on the understanding of memory images by a consideration of some of the aspects of abnormal forgetting. Abnormal forgetting may occur on the basis of the actual destruction of brain tissue, as the result of disease or an accident, or by the temporary malfunctioning of brain tissue as the result of disease or an accident, or by the temporary malfunctioning of brain tissue as the result of concussion or of certain poisons affecting the central nervous system. In either case, two sorts of effect may be noted sometimes in isolation and at other times mixed together.

The first of these is called *amnesia* and the symptom of this condition is the loss of concrete memory images. This loss may be entirely specific so that only concrete visual images are affected while auditory and kinesthetic concrete images are in no wise affected. In a few cases one may find an almost total loss of concrete images of one or more modalities without the verbal images of the same modalities effected in the least.

This is the basis for the statement earlier in this chapter that there was a real psychological basis for the distinction between verbal and concrete images within a given sensory modality.

An interesting example of amnesia is of a young man examined some years ago by the author. He was an intelligent young chap working in the drafting room of a telephone company with a knowledge of charts of wiring and with a practical background of experience with telephone lines and electrical apparatus in general. One evening he drank some alcohol which was apparently poisoned and which resulted in unconsciousness and gave evidence of having poisoned parts of his nervous system.

When he regained consciousness the next morning he discovered that he was on a train and to this day has no knowledge of how he got there. A talk with the conductor indicated that he had a ticket for a town at the end of the line but he was unable to remember any connection which he had ever had with this town. Having nothing to do until his train arrived at its destination, he examined the contents of his wallet and of his pockets, and while doing this, performed a truly excellent bit of logical thinking. He found in his wallet four visiting cards all with the same name. He decided that this must be his own name inasmuch as no one would carry about so many cards with the name of another individual.

He also found a card with an address in the city to which his train was going. On arrival he took a cab to this address, under the guidance of the railroad officials, and ringing the bell, asked if anyone there knew him. What happened can best be told in his own words. "A man came to the door who said he was my brother. He looked honest and there seemed no reason why I should not believe him." The brother brought him to the psychological laboratory where he was examined to determine the extent of his imaginal loss. There was no evidence of the retention of any visual concrete images. He had failed to recognize his brother; he was unable to explain a plan of electrical wiring which was the sort of thing he worked on daily in his drafting room. He was unable to recognize many concrete sounds, which indicated a loss of auditory concrete images, although this loss was apparently not complete. He was given pieces of electrical apparatus with which he had been familiar and he was totally unable to wire them, which indicated probably a loss of kinesthetic concrete images as well as of visual concrete images. This loss of kinesthetic concrete images was further evidenced by his being unable to use simple tools, which were handed to him both with and without his seeing them. If you, with your normal memories, should be handed a piece of wood, a screw and a screw driver, it is certain that you would have kinesthetic images of the use of the screw driver. This man, without these concrete kinesthetic images, had no knowledge of their use. He might just as well have been handed objects new to his experience.

On the other hand, there was evidence that his verbal images of all the different modalities were unaffected. He could speak and understand spoken language which indicated a proper functioning of kinesthetic and auditory verbal images. He was able to read, and indeed, he could read French as well as English and could translate French into English as well as one would expect from a high school graduate. He was given an intelligence test such as those given in the army during the war. These are almost entirely verbal in character and he achieved a score high enough so that it would have secured for him an officer's rating.

We found out from his brother that during the war he had been interested in some of the then newer types of armament such as airplanes and submarines. When shown a picture of an airplane and submarine he was totally incapable of naming either or of pointing out which was which; then the names were given to him. When the pictures were removed, it was found that he could give an adequate verbal description of either with regard to its form, mechanism and uses. Having verbally described these objects, he was again shown the pictures and was unable to identify them. Here is conclusive evidence of the loss of the concrete images which was total for vision and nearly total for audition and kinesthesis, without the verbal images of these same modalities apparently being affected at all.

These losses of concrete images were only *temporary*. We are dealing here with a temporary amnesia, therefore. Medical treatment over some days eliminated the poisons which were interfering with the functioning of the nervous system. Then rest and some slight reëducation were sufficient in this case for the return of all of these temporarily lost concrete memories, but sometimes the loss of concrete memories in amnesia is permanent. This is true especially in cases where there has been actual destruction of brain tissue. But even in these cases it is sometimes possible to reacquire some or all of the lost memories by means of intensive reëducation. But in this case there is modification of new brain areas other than those which have been destroyed. This modification can only be accomplished by restimulation and indeed it means that new memory images have been acquired.

There are many cases in the literature which emphasize the great degree of specificity which may be present in amnesia. For example, a man may have lost all visual concrete images without his visual verbal or auditory and kinesthetic concrete or verbal images being affected at all. Such a man coming down the street might see a group of what seem to him perfectly strange children playing and only when he hears the voice of one of them does he recognize him as his own son.

Aphasia, as contrasted with amnesia, on the other hand, is characterized by the abnormal loss of verbal images without the concrete images of these same modalities being affected at all. In aphasia, as in amnesia, there may be great specificity of the loss within a particular modality. If the visual verbal images are lost the patient will be unable to read; if the auditory verbal images are lost he will be unable to understand spoken language and if the kinesthetic verbal images are affected, he will be unable to speak or write. These are known respectively as visual aphasia, auditory aphasia and motor aphasia. Some idea of the degree of specificity may be realized by considering a case which was described in the literature some years ago. This was a young woman who was suffering from visual aphasia to a marked degree. She was totally unable to read because of the complete loss of visual verbal images. It was found that she could read if she was allowed to trace the letters with her finger and hence obtain kinesthetic verbal cues. She was given intensive training in an effort to build up new visual verbal memories but without success. To the surprise of her teachers, she was suddenly able to read very slowly, but with reasonable accuracy without tracing the letters with her finger. It looked as if the training had established new visual verbal images as the basis of reading. It was then discovered that there was no evidence that she had acquired such new images of a visual verbal sort. What she was doing was to trace the letters with the tip of her tongue on back of her closed teeth, and by this means, she was obtaining kinesthetic verbal cues.

One other fact regarding abnormal forgetting, either amnesia or aphasia, is of greater theoretical than practical importance. In the case of a sudden injury resulting in short temporary amnesia or aphasia, one not only completely forgets what has happened during the period of unconsciousness, but he also is unable to recall what happened some seconds or even minutes *before* the blow. This aspect of abnormal forgetting of what happened just before the blow is called *retroactive* amensia or aphasia. A player kicked in the head during a football game may continue to play, but not only will he be unable to recall what happened after the injury, but he may actually not remember a brilliant run which resulted in his making a touchdown, which he himself had made even some minutes before he received his injury. For this reason, if you find that you are going to be run down by an automobile and feel sure that you will be knocked unconscious, there is no use trying to read the number of the license plate because you will not be able to remember it anyway after you regain consciousness. This retroactive effect in amnesia, which involves the loss of memory images before a blow, is of certain theoretical importance because it indicates that a certain amount of time must elapse after stimulation for the modification of nerve tissue to become set in the nervous system and thus to become effective as the basis of some future image of the experience. If anything occurs before the necessary time has elapsed so that consciousness is disturbed or eliminated totally, the modification apparently does not become set and memories of these experiences may never be recalled.

Throughout this chapter we have emphasized the fact that the images are the basis of memories and that each image is the result of a particular perceptual experience. Images are better explained in terms of modification of brain tissue as the result of sensory stimulation than by the more popular appeal to a subconscious mind in which these memories are stored. The facts of neural physiology as well as those of abnormal forgetting support this view. Throughout the discussion there has been an emphasis on the specificity of these memory images with regard to the particular modality of perceptual experience as well as on the question of whether the experience has been concrete or verbal in character. Therefore one must discard any concept of memory as a mental faculty separate and distinct from other mental faculties. Indeed we should properly speak not of memory at all but rather of memories. We have a visual concrete memory, a visual verbal memory, a kinesthetic concrete or a kinesthetic verbal memory and so on, depending in part upon the perceptual modality of the image in consciousness and partly upon the sensory modality of the original experience.

QUESTIONS

1. Why is it necessary to deal with memory images?
2. What is an after-image? What differences exist between memory images and after-images?
3. On what grounds may the theory of the subconscious be criticized?
4. How may images be classified?
5. What differences in the properties of the image exist among the images of the various sense modalities?
6. Distinguish between imaginal endowment and imaginal type.
7. In what way is imagery related to special capacity?
8. In what way may the consequence of defective imagery be lessened?
9. What are the experimental facts concerning the nature of the course of the memory image?
10. What is meant by amnesia? Of what systematic importance is amnesia?
11. What is meant by aphasia?
12. What is retroactive amnesia or aphasia?

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Chapter XII

MEMORY—SIMPLE AND COMPLEX

In the last chapter the memory image was described and the treatment of it emphasized the fact that the image is the basis for memories. When some past experience is recalled in consciousness, the conscious content is found to be made up of memory images. The last chapter, then, may be considered a qualitative treatment of memory; a treatment of what is in consciousness at the time of recall. In this connection there was even described what happens to the memory image during forgetting. The present chapter is concerned more largely with the quantitative aspects of remembering.

Will the reader do the following simple experiment? Have before you a sheet of paper and a pencil. On page 197 you will find a series of numbers. Do not look at them until you have read these instructions. All of the series are of different lengths running from 3 to 15 digits. Either read these numbers to yourself, or better still, have someone else read them at the rate of about one digit per second to you. Read the first line of three digits only once and immediately write it down exactly as you have seen or heard it. Then read the second line of four digits just once and immediately write it down exactly, and so on, writing exactly as much as you can remember of each line through the 15 digits, immediately after only a single reading. When this is completed, continue with a precisely similar procedure to read through the sentence below the list of digits just once, or have it read to you just once and immediately write this down as well.

After you have done all of this compare your written production with the list of digits and the sentence. In scoring your work, the reproduction must be exactly identical with the original to be counted correct. Wrong digits are of course incorrect but also any errors of omission, addition or even transposition of the order in which you have written the digits must be counted as incorrect. Your score for this test is the number of digits in the longest series which you have been able to reproduce in the correct order immediately after a single stimulation.

6 2 8
8 1 6 7
6 8 1 7 5
3 6 9 1 4 7
2 9 6 8 5 1 3
9 1 7 4 2 6 3 5
1 9 2 4 7 3 6 8 5
3 7 6 2 9 5 1 4 8 6
9 3 7 5 1 6 4 2 8 5 7
6 2 5 9 3 8 1 4 7 5 2 8
8 5 7 4 1 9 2 6 3 5 1 8 6
9 3 6 1 7 4 2 5 8 3 7 9 6 8
7 2 1 6 8 5 9 4 6 5 7 8 2 1 4

The sentence is as follows: "History tells us that the date of the Custer massacre was 1876."

It is certain that very few readers will have been able to immediately reproduce all of the series of numbers up to 15 digits without error. It is almost certain, on the other hand, that each reader will have had little difficulty in reproducing the sentence which he did immediately after the series of 15 digits, without error. But it may at once be pointed out that the sentence contains 15 units,—either words or digits. This is an indication, at least, that one must differentiate between two sorts of processes of remembering. One sort of remembering process is represented by the reproduction of the lists of digits and the other by the sentence. The reader will, in all probability, have had no difficulty in reproducing the sentence correctly after a single reading but he certainly had great difficulty, or found it impossible to reproduce correctly the list of 15 digits (the same number of units as were in the sentence) under exactly the same conditions.

The fact that we must differentiate between two totally different kinds of process of remembering may be further emphasized. Close this book and turn your paper face down so that you are unable to see any of this material further. Certainly several minutes will have elapsed since any of this material was in consciousness. Will you now recall the date in the sentence and write it on the back of your paper. Probably you will have little or no difficulty in doing this. Now recall and write on your paper the list of four digits. Quite probably you will find that you are unable to do this after this delay of only several minutes. It is certain that you will recall these four digits with much more difficulty and with much less assurance than you were able to recall the four digits in the date after a similar delay. It may now be pointed out that both the date and the series of four digits contain exactly the same numbers. The date is 1876 and the series of four digits has the first and second and the third and fourth of these digits transposed, so that it reads 8167.

Thus we must differentiate between the two kinds of process of remembering. The first, exemplified by the simple list of digits is called *perseveration*. The second, illustrated by the sentence, has been called *logical memory*. Both logical memory and perseveration have several aspects in common. Both are dependent upon previous stimulation. The conscious content for both is the memory image. But the difference between perseveration and logical memory are equally apparent. By perseveration one may recall relatively less material and the recall may be made only over a relatively shorter time than for logical memory. These two facts have been demonstrated in the experiment above when you found that you could immediately reproduce the sentence of 15 elements but not the list of digits of the same length and when you found that, some little time later, you could recall the four digits of the date but not the same four digits in a different order in the first part of the experiment.

Perseveration must be explained in terms of a modification of brain tissue as the result of stimulation. But for perseveration this modification is transitory in character and is not like the more permanent modification which is the basis for logical memory. Perseveration is a fine descriptive term for this sort of conscious process. The consciousness seems to persevere only for a short time so that one might almost compare it with the sensory after-image and call it a memory after-image. Experimental results indicate that the number of digits which may be immediately reproduced after a single stimulation is about 7 to 9 for the average college student. There are very considerable amounts of variation between individuals in this respect. It has been found that there is a relationship between the range of attention and perseverative ability. If one's range of attention is restricted, one is almost sure to have poor perseverative ability as well. Good perseveration, as measured by the number of items which may be immediately reproduced' is almost always accompanied by a relatively wide range of attention.

Perseveration, as a mental process, is much more frequently employed than most of us realize. When one calls up a new phone number, all too frequently one has the following experience. One reads the number in the phone book and then usually repeats it to himself until the operator asks for the number. This is then given to the operator. After a short time, the operator may say: "Sorry, what number were you calling?" And all too frequently one must answer: "Wait a moment, I have to look it up again." This failure to recall the number after such a short delay is because by perseveration alone, one cannot again recall an item even after such a short interval of time. It is wise to write down the telephone number in the first place, anticipating such a delay.

There is evidence that perseveration is a process which has a congenital basis. One seems to be born with the ability to recall immediately after a single stimulation only a certain number of items and no amount of training can effect an increase in the limits of this ability after one has reached adult age. There is a definite and well known improvement in the limits of perseveration during childhood, however. The average child of 3 years will correctly repeat only 3 digits; that of 4 years will on the average repeat 4 digits; 5 digits are found to be the average reproduction only at 7 years and not until 10 years of age have been reached will the average child be able to correctly repeat 6 digits immediately after a single stimulation by perseveration alone.

There are some ways in which the number of items, which may be recalled through perseveration, may be apparently but not actually increased. One way of apparently increasing the number of items which may be so recalled is by using dissimilar elements. Such a system is employed in the construction of telephone numbers used in some large cities. A number will appear in the telephone book as "POPlar 2677 J," in which Poplar is the name of the exchange, the four digits are the number of the trunk line and the final letter indicates that it is the first party of a two-party line. Thus there are six items in the form of such a number. If the six items were of an identical sort they would be beyond the perseverative ability of many persons otherwise perfectly able to use the telephone. This number might just as well be written with a digit indicating the exchange and another for the indication of the party line and thus it would appear, if Poplar was the first exchange, as 126771. Writing it in this way would save much space in the telephone book and would involve a much smaller cost for setting up the type. But experimental researches indicate that what the telephone company would save in their printing bill would be more than lost in wrong calls, because six identical elements would be beyond the perseverative range of so many more people than the present form of six items made up of three dissimilar sorts of elements.

Another method of apparently increasing the number of items which may be immediately recalled through perseveration is by grouping the elements. Such a grouping may be part of the stimulation situation or the grouping may be the result of the reader's own contribution and thus be surely subjective. This principle of grouping is made use of in the form of automobile license plates of some states in this country. An automobile license plate of the grouped form of 1–672–835 is really no more easily perceived than the ungrouped 1672835. But due to the limitations of perseverative ability, the grouped form is much more apt to be immediately recalled correctly than the ungrouped form. But even so, the Bureaus of Highways in most states complain that a very large proportion of automobile license numbers reported to them are incorrect. People, when they have seen an infraction of the law which they wish to report, have trusted to their perseverative memory which has proved completely inaccurate for recall after the lapse of a long interval. If you wish to report an automobile number, you should write it down at once rather than trust your ability to recall it after a longer interval of time.

If you are asked now to recall the perseverative material of four digits from the experiment a few pages back, you will find that you are probably not able to do this directly. But you may succeed by resorting to the device of recalling the date and then logically passing through the process of transposing the pairs of digits. Instead I shall ask you to recall the list of five digits which were presented to you some time ago as perseverative material, and which it is certain that you were immediately able to reproduce at that time. One can be sure that very few individuals will be able to reproduce this series of 5 digits after the interval of time necessary to reach this point in the text. You have been asked to try and make this recall at this place merely to again emphasize the distinction between perseveration and logical memory. Logical memory, or what we think of as memory proper in popular thinking, we have found is characteristized by recall after a long interval of time and by the possibility of recalling a great *many* items of one's own past experience.

There are four sorts of problems concerned with logical memory: (1) the problems of *learning*; (2) the problems of *retention*; and (3) those of *recall*; and (4) those of *recognition*. In this chapter some of the problems of learning will be briefly treated.

The experimental literature on the psychology of learning is enormous and some of the problems are important in any systematic treatment of psychology. But the problems of learning constitute a principal part of the special field included in *educational psychology* and an extended treatment of these problems would seem to be out of place here. The reader is referred for their consideration to one of the several texts in educational psychology given at the end of this chapter.

For our present purpose, it is necessary to emphasize that learning is the process by which a modification is effected in some part of the brain by stimulation, which will be the basis of a recall at some later time, provided this modified brain area is restimulated. The experimental literature of learning is primarily concerned with a study of methods to make this modification more effective, either by producing the same degree of modification with a smaller expenditure of time and effort, or by producing a greater degree of modification with the expenditure of the same time and effort. It has been discovered experimentally that many factors make for greater learning efficiency but only a few of these will be treated in the present text because only these few have systematic importance.

One can add little more to the second problem of memory, namely, *retention*. Retention must be thought of in terms of the modification of brain tissue brought about by the stimulation during learning. This was explained in some detail in the last chapter in the discussion of the basis for the memory image.

The third memory problem of *recall* presents certain aspects of the greatest interest to psychology. It has already been stated several times that a memory recall can best be explained in physiological terms. This involves the following three stages: (1) a stimulation modifies brain tissue; (2) this modification of brain tissue persists over a period of time; and (3) if the modified brain area is restimulated, this will result in the appearance of an image in consciousness similar to, but not necessarily identical with, the previous perceptual experience. The problem of recall, therefore, really amounts to an explanation of how one may restimulate the modified brain area. It consists primarily in an explanation of how one may get nerve energy to this modified part of the brain. Psychologists have explained how one may restimulate a modified brain area in terms of the principle of *association.*

The reader is warned that association is not to be thought of as a conscious process such as sensation or the memory image. We are not aware of association directly. It is merely a principle of explanation. We recall one idea and then recall another idea. This is all that one may discover from a study of consciousness. But, after the two ideas have been recalled in succession, one may realize that both of these ideas were experienced simultaneously or in immediate succession at some time in the past and we say that an association was formed between them. If such an associative bond has been formed between two ideas, one can say that the subsequent presence of the first in consciousness is responsible for the second one being in consciousness as well. Thus, if one thinks of white, he is also apt to think of black. Cup and saucer; horse and wagon go together in consciousness just as frequently as they do in experience and they go together in consciousness simply because they are so associated in experience. If wagons were not found with horses in our common experience, the strong association between the two ideas would not have grown up.

A simple psychological statement of this principle of explanation called association would run something like this. If two ideas have been experienced together in the past, the presence of one of these ideas in consciousness in some subsequent recall tends to be accompanied by the presence of the other idea as well. Items of experience which have occurred together tend to recur together in memory. This principle has been called the *primary law* of association. The name *Law of Contiguity* has been given to it because it emphasizes the basis of association in the contiguity in space and time of the several ideas which become associated during the original period of stimulation.

Contiguity is by no means the only primary law which has been suggested by psychologists in the past to explain the principle of association. Other laws often repeated are those of similarity (such as the association of the ideas of man and woman); contrast (such as the association of the ideas of giant and dwarf); and cause and effect (the idea of heat follows that of fire). But in every one of these three proposed primary laws of association, it can be demonstrated that the several ideas must have been together in consciousness at some time in the past. Otherwise the cause and effect, the similarity or the contrast would not have been perceived between the several ideas. And it is because of this contiguity in consciousness that the associations are formed between the ideas and not because of the other logical relationships between them. Contiguity in space and time may be accepted as the sole primary law of association.

It can then be emphasized that one's associations are as much due to one's own individual experiences as are the particular ideas themselves. It is the fact that two or more ideas were experienced together in consciousness which is the basis for the formation of these associations. Perform this very simple experiment. In a short time, in this text, you will come to what shall be called a *stimulus* word. You are asked merely to note the first idea that comes into your consciousness after your perception of the stimulus word. You are asked to note what has been called the *reaction word.* You will recognize that the stimulus word constitutes the first idea of an associated pair and that the reaction word constitutes the second idea of this same associated pair of ideas. The first stimulus word is "table." The results of the study of the reaction words of one thousand normal individuals indicate that a total of 124 different reaction words occurred when this stimulus word was given. Even an outsider, not knowing the individual past experience of any of these one thousand subjects, can recognize that the ideas represented by the different reaction words must have been contiguously or simultaneously in consciousness with the stimulus idea at some time in the past experience of these individuals. Many of these reaction words relate to eating, for example, or to materials used in the construction of a table. But slightly more than one-fourth of these one thousand subjects had the idea "chair" first in consciousness immediately after the word "table" had been given. And slightly more than half of the one thousand subjects replied with one or another of the following five obviously associated ideas,—chair, cloth, eat, furniture or wood,—all obviously in consciousness some time in the past with the idea of table.

Try another stimulus word, namely "eagle." It was found that 568 of the one thousand subjects had the associated word "bird" in consciousness, although 108 other ideas were recalled first by at least one of these subjects. And each of these 108 ideas has an obviously associated meaning with the stimulus word "eagle." Results such as these would indicate that there exists a certain *community of ideas.* One finds that there are certain ideas which are frequently associated with other ideas by a large proportion of individual subjects. Indeed one would expect that individuals raised more or less in similar environments and more or less subjected to the same groupings of perceptual experience would have built up similar association. The results of this experiment indicate the truth of this supposition. The educational system of some years ago, perhaps somewhat more so than that of today, tended to give all pupils similar patterns of perceptual experience. Thus it may be readily understood that, on the basis of these similar patterns of perceptual experience, one can only expect similar associative patterns of recall.

The primary law of contiguity for association can be better understood, perhaps, if it is translated from purely psychological terms into physiological terms. It has already been emphasized that association, like the image, can be best understood by an explanation in terms of the nervous system. Such a physiological explanation is simple and would run as follows. If two brain areas are stimulated simultaneously and are modified as the result of this simultaneous stimulation, a pathway of discharge is built up between them. Thus, if one of these areas should be restimulated, some of the nerve energy will go across this pathway and stimulate the second area as well. As yet physiology cannot give a final description of these pathways between modified brain areas but several plausible theories exist which describe them. The problem of recall, which is really the problem of getting nerve energy to a particular modified brain area, is thus best explained by reference to these pathways of discharge between brain areas, which are built up by the particular experience of the individual.

The importance of association for recall can best be illustrated by describing a demonstration which the author gives each year to his class. The class is asked to prepare a list of thirty common nouns, such as chair, automobile, paper and the like. A blindfolded assistant is then brought into the room and this list is read to him just once. After the single reading, he demonstrates that he is able to repeat the list of words forwards and backwards; that he can give the position of any word in the list or the word for any position or any other combination which may be asked for, such as every third word in reverse order. After this demonstration, and by this time the class has been looking at and considering the list for well over a half hour, it is rubbed off the board and the class is asked to reproduce the list forward. It is seldom that any member of the class is able to do this without error.

The assistant's ability to give this demonstration is not a trick. The list of thirty common nouns is one actually prepared by the class and is unknown to the assistant who actually never sees it, because of his blindfold, and who hears it read to him only once. If you attempted to learn such a list, you probably would try to associate the first word with the number 1, its position in the list. Thus if the first word was "cow," you might say to yourself "one cow." If the seventeenth word was "automobile" you might try to make the association "seventeen automobiles." Obviously such associations would be inadequate for a list as long as thirty items.

The demonstration is performed by the assistant having first learned a list of key words. He has spent considerable time in the mastering of this list and the position of each key word in the list. His key word for the first position happens to be "altar." The list is so well learned that, whenever he thinks of "one," he also thinks of the associated "altar" and, whenever he thinks of "altar" he also thinks of the associated "one." When the first word of the list prepared by the class is read to him, his idea "altar" is in consciousness and he makes an association between "altar" and "cow." The more bizarre this association, the better chance there is for the recall. For example, he may have a visual image of a cow standing on an altar. When "automobile" is given as the seventeenth word, he already has his key word "awning" in consciousness and he at once associates the key word "awning" with "automobile," the seventeenth word in the class list. For example, he may have a visual image of an automobile with a gayly striped awning covering it. His associations, then, are made between each word of the class list and the key word appropriate for this position.

In the recall, let us say that some member of the class asks for the position in the list of the word "cow." The consciousness of the demonstrator would be something like this. When he is asked for the position of "cow," he at once has his associated visual image of a cow standing on an altar. The presence of "altar" in consciousness brings up the previously memorized associated idea "one" and he reports that "cow" is the first word of the list. Or someone may ask for the seventeenth word. At once the memorized association comes to consciousness "seventeen—awning." Then the presence of the idea "awning" in consciousness brings up the associated idea of the awning-covered automobile and he is able to report that "automobile" was the seventeenth word.

Such forced associations are really the basis of many of the existing "memory schemes" or alleged methods of improving one's memory, which are sold today to a great many people. Actually the plan is cumbersome and is of little practical use. Naturally one cannot have a prepared memorized list of too great length and naturally one cannot use a given key word for several items simultaneously or one would be apt to recall the wrong reaction word for any given situation. Any one can be prepared to give this demonstration within 24 hours. All that would be required would be to spend considerable time preparing and learning the list of key words each associated with its position in the series. Although the practical value of such a scheme is doubtful, it provides an excellent demonstration of the efficiency of association for recall, and indeed of the necessity of association for recall. It emphasizes that if two ideas are simultaneously in consciousness, then the subsequent presence of one tends to bring the other into consciousness also. The demonstration emphasizes the fact that recall is based upon the building up of pathways of discharge between two modified brain areas as a reasonable explanation.

Recognition, the fourth problem of memory, is really exceedingly simple. It also involves association as its basis. In simple recall one has two ideas in consciousness,—the first idea and a second idea which is associated with the first and recalled by it. In recognition, however, one has an idea associated with an actual present perceptual experience based upon the stimulation of the moment. The result is that this first conscious content, which is perception and not recalled idea, is apt to be relatively more intensive, clearer and more detailed than a recalled image would be. Experimental results indicate that recognition is more efficient than recall and this difference is based on the first member of the associated pair being more effective in recognition because it is a perceptual and not an ideational content. Any postage stamp collector, with perhaps thousands of different stamps in his collection, will tell you that he would be totally unable to ennumerate the items which he possesses by recall. But he is able, almost without error, to recognize whether or not he possesses any particular stamp which is shown to him.

Until now we have spoken of association as if it were a connection between two ideas. This is true inasmuch as idea A present in consciousness may bring idea B into consciousness as the second member of a pair. But then in turn idea B in consciousness may bring idea C into consciousness and so on more or less indefinitely. Conscious recalls, therefore, may be considered as a series producing a *train of memories* in which each second member of an associated pair may become the first member of another associative pair. If you will take a piece of paper and rapidly write down 25 different words haphazardly and then carefully consider what you have written, in most cases, you will find that each successive word has some sort of an associative connection with the word which is before it in your list. Since it is through association that we have the only avenue through which an idea may be recalled to consciousness, a truly haphazard train of thought would seem impossible. The existence of such trains of associated ideas is perhaps best demonstrated by the recall of memorized poetry or other verbal material.

We have spoken of association as a principle of explanation rather than a conscious content. Association has been described in terms of the primary law of contiguity which is best stated in physiological terms. This, we repeat, says that if two modified brain areas are stimulated simultaneously, a pathway of discharge is built up between them so that, if one of these areas is restimulated, some of the nerve energy goes across the pathway to the other area as well. Thus the primary law of contiguity accounts for the existence of such pathways between brain areas.

The so-called *secondary laws of association* have to do with the relative strength of associative bonds or with the relative efficiency of such pathways. For the normal mind, we must think of associations as being more or less in the form of constellations. If you should be given the stimulus word "Christopher Columbus," you may have any number of associated reaction words,—America, Isabella, discovery, Genoa, Santa Maria and what not besides. But one of these ideas will have been the word which appeared first in consciousness after the stimulus word and one may therefore consider that the associative bond between the stimulus idea and the reaction idea was stronger than any of the other associative bonds. The purely schematic chart is an attempt to reproduce such an associative constellation. The reader is warned not to take this chart too literally and he is certainly not to consider the circles as representing individual brain cells and the lines connecting them as individual nerve fibers. The situation is much more complex than this. In this schematic chart (fig. 66) there is a central circle which represents the brain area so modified that if it is restimulated we shall have the idea "Christopher Columbus" in consciousness. Surrounding this central circle are the five circles representing the modified brain areas for such ideas as "America," "Isabella," "Discovery," "Santa Maria" and "Genoa." The lines drawn from the central circle to each of these five circles indicate associative pathways of discharge so that the nerve energy from the central circle may get to any one of the others. The arrow, just above the central circle, indicates some outside stimulation, such as the stimulus word being said to you, so that some excitation gets to the central circle. If your first reaction word was "America," it indicates that this pathway of discharge was, at the moment, stronger than any of the other possible pathways of discharge from the central area to surrounding areas.

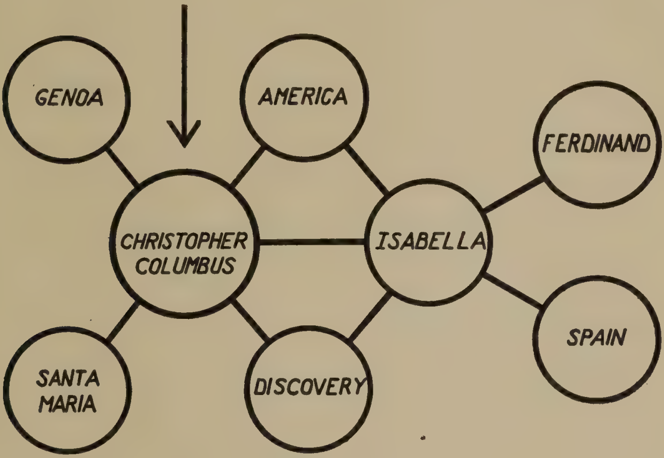

Fig. 66

In this schema, the arrow just above the central circle is important. By this it is indicated and emphasized that no train of thought just begins spontaneously. Every association and every train of thought is initiated by some external stimulus which starts it going. But the situation is still more complicated than this. It will be seen that lines have been drawn, representing pathways of discharge, between the area marked "Isabella" directly to "America," "Discovery" and "Santa Maria." By this we have indicated that the idea "Isabella" may also be the center of an associative constellation and that any of these other ideas may be in associative connection directly with "Isabella." We have still further augmented this constellation by the addition of circles representing the ideas of "Ferdinand" and "Spain." Obviously further complication would make the schema unreadable. But all of the essential facts of associative pathways of discharge between modified brain areas are here represented.

Those factors which affect the strength of the pathways of discharge and are described by the secondary laws of association. They are (1) *repetition,* (2) *vividness,* (3) *emotional congruity* and (4) *recency.* These have been selected as the most important from a larger list of secondary laws of association which have appeared in the psychological literature from time to time.

Repetition is an obvious factor in the establishing of strong associative bonds. The more frequently two ideas are together in consciousness, the stronger will be the associative bonds between them. Thus the more frequently two ideas are together in consciousness, the more apt the presence of one of them is to recall the other one also. The recognition of the validity of this secondary law of frequency or repetition is the basis for all drill in primary education. Thus 2 times 2 equals 4 must be repeated over and over again until one can be sure that the associative bond, really represented by the equals sign, is strong enough so that the presence of 2 times 2 in consciousness will be immediately followed by the associated idea 4 and by no other idea. If you wish to memorize a poem it is necessary to repeat it a number of times as the basis for subsequent recall. There is a mass of experimental results which indicate the importance of repetition for the formation of strong associative bonds and which indicate the relative efficiency of various degrees of repetition in learning different sorts of materials.

It is surprising how many associations are acquired only on the basis of sheer repetition. We have already noted the multiplication tables and other number combinations. To the child's mind, 3 plus 4 might just as well equal 9 as 7. He must learn the correct association and he can only do this through sheer repetition. It may be suggested, for example, that the learning of the names of objects in the early acquisition of language has its basis in pure repetition. Language, after all, is a collection of purely arbitrary verbal symbols. A "dog" does not necessarily look like a dog,—in Germany it looks like a "Hund" and in France it looks like a "chien." It is impossible to suggest how the formation of associative bonds between the object and its verbal symbol could have become so well established except through many repetitions of the concrete and verbal ideas simultaneously in consciousness.

The next secondary law of association, *vividness*, states that the more vividly two ideas are together in consciousness, the stronger will be the associative bonds between them. This presents a problem which has been difficult for experimental demonstration largely because of the difficulty of the experimental definition of vividness. Vividness is not necessarily intensity of stimulation although frequently great intensity of an experience seems to increase its vividness as well. What one means by vividness, and thus the demonstration of this secondary law of association, may be perhaps best illustrated by a story. It is said that a father and his young son were standing in the street watching the funeral procession of one of the assassinated Presidents of the United States. As the body on the gun carriage went by, the father struck the child and knocked him down in the street. The child came up crying and asked what he had done. To which the father replied: "My son, you did nothing wrong at all. But I want you to always remember that you saw this President's funeral." Such treatment is rough on the child, but it is good psychology of a sort. The father provided a vivid enough idea associated with the funeral so that there would be established stronger associative bonds than otherwise. It is certain that in your own experience, you can surely find some association which is easily recalled, in spite of a single repetition, simply because of the vividness of the original experience.

The third secondary law of association has been called *emotional congruity.* This law says that stronger associative bonds are formed if the ideas simultaneously in consciousness fit into, and are therefore congruous with, your general emotional background. This is the factor which takes into account your own personal likes and dislikes and your particular personal *interests.* If one is more interested and likes better to work in science than in literature, he is apt to learn better, to form stronger associative bonds for the scientific material which he likes than for the literary material which he dislikes. It is wide experience in colleges that a number of students do not learn mathematics well. They do poorly in this subject, and indeed, seem almost resistant to the formation of mathematical associations although they frequently do very well indeed in other fields. One finds that almost invariably such an individual dislikes mathematics. The dislike may have its basis in a real inability to do this kind of thinking because it involves the associations of symbols rather then concrete ideas. But very frequently the basis for the dislike may be perhaps in early failures or in the boredom from the repetitions necessary for early number drill. It has already been indicated that the necessary associations for the fundamental number combinations can gain sufficient strength for efficient practical use only through many repetitions. Or the dislike may have its basis in hearing the talk of older pupils even before he has ever started mathematics at all. Such an individual, with this dislike well established, finds himself in a vicious circle. Continued failure inincreases the dislike. And the stronger the dislike the more difficult the formation of strong new association bonds will be because the ideas involved do not fit into the student's interests or into his general emotional approach.

The fourth secondary law of association is that of *recency*. This law says that the more recently two ideas have been together in consciousness, the stronger will be the associative bonds between them. This is merely another way of stating the perfectly universally known fact that forgetting proceeds with the lapse of time. A very great deal of experimental work exists on this problem so that psychologists know very much indeed of the quantitative rate of forgetting. The first experiment in this field was performed only 50 years ago. It has been repeated many times with similar results. This experiment is so important and it is so well illustrates the problems which must be faced by an investigator attacking a new problem in psychology that it is worth while to describe it here in some detail.

If one desired to study the rate of forgetting, it would be necessary to find some material which must be learned so that the degree of forgetting of this material could be measured. But one wishes to measure the degree of forgetting after different intervals of time. It is obvious that if one used the same material and recalled it after an hour and again after a day and still again after two days, that the first two recalls would constitute relearnings of the recalled materials which would affect the later results. Thus it becomes necessary to have each set of learned material recalled only once during the experiment. Also to help eliminate chance factors, it is necessary to repeat the recalls, after each interval of time after learning, a great number of times, and for this purpose, new materials for learning must be used in each instance.

The experimenter is thus faced with the problem of finding a large number of different sets of materials to be learned each set of which shall present approximately the same degree of difficulty for learning as every other set. The original investigator of this problem tried many kinds of materials. Sections of prose presented markedly different degrees of difficulty for learning and it was found that different stanzas of even the same poem were markedly different in this respect as well. Lists of disconnected words also gave markedly different learning times. Lists of digits proved satisfactory so far as presenting the same degrees of learning difficulty, but unless one uses relatively large numbers in compiling his lists, there are not enough numbers to go around without repetition for the preparation of a large number of lists to be learned. The experimenter solved the problem by the invention of what has been called the *nonsense syllable.* This consists of a vowel preceded and followed by a consonant in a nonsense combination such as ZUB. Any syllable which has an obvious associated meaning such as MEX which frequently stands for the abbreviation of Mexico, is eliminated. It was found that there were a sufficiently large number of possible nonsense syllables, and that lists of them had about the same degree of learning difficulty. It was decided then to choose as material for learning lists composed of 12 such nonsense syllables.

The next problem to be solved was how to be sure that each list was learned to the same degree as every other list so that the results of the amount forgotten could be compared. It was decided to expose these syllables visually one at a time with a constant and known rate of exposure. The investigator adopted the criterion of learning as the ability to correctly anticipate each syllable in the list just before it appeared in the window through which it was exposed. After the first time that the subject could first correctly anticipate each syllable, the exposures were stopped and the material was considered learned. It will be noted that this material was just learned to the point of first errorless repetition.

It was then necessary to wait for a period of time before one could determine how much of this material had been forgotten. The following periods were chosen after which the amount forgotten was to be tested: 20 minutes after learning, 1 hour, 8 hours, 1, 2, 6 and 30 days and, in another experiment 120 days.

At the end of each of these periods it was proposed to test the amount of the learned material which had been forgotten. Several ways of doing this are apparent. One could determine how many items could be recognized. This recognition method might have been valuable for determining the amount forgotten after long intervals of time, but it was inadequate for the shorter periods, inasmuch as all the material would probably have been recognized after an hour or even a day, and the experiment would have determined that, measured by this method of testing, there had been no forgetting at all over these short intervals of time. It is possible, and this is perhaps the most obvious method of testing the amount forgotten, to ask the subject to reproduce the material after an interval of time and to discover how much he was not able to recall. Again this method might have been highly satisfactory for testing the amount forgotten for the shorter intervals of time but not for the longer. One could not expect a subject to reproduce any of a list of nonsense syllables after a four month interval particularly as he would have learned many other lists in the meantime and he would thus not know which list was desired for the particular recall.

In order to solve this problem, the investigator developed a relearning method to test the amount forgotten. This consisted in the following procedure. The number of repetitions necessary to just learn the material in the first place was noted. After an interval of time the subject was asked to relearn the same series of nonsense syllables to the same point of errorless anticipation of each syllable just before it appeared. If it took fewer repetitions to relearn the material than it took to learn it in the first place, a saving would have been effected by the previous learning indicating that something had been remembered. The percentage remembered was determined in the following simple way. The amount of saving was first determined by subtracting the number of repetitions necessary for relearning from the number of repetitions necessary for the initial learning. Then the saving divided by the repetitions necessary for the original learning gave an index of the percentage remembered. This method of calculation of the amount remembered will become clearer from a consideration of the two examples given below.

Repetitions required to learn	10
Repetitions required to relearn	2
Saving effected	8

Thus in this case $\frac{8}{10}$ or 80 per cent will have been remembered. On another case:

Repetitions required to learn	10
Repetitions required to relearn	9
Saving effected	1

Thus $\frac{1}{10}$ or only 10 per cent will have been remembered after the time interval.

Because of the method of calculating the amount remembered in terms of the degree of saving effected in the relearning as compared with the original learning, this mode of procedure has been called the *savings method.* As a matter of fact this method will give a much better score of the amount remembered than one would get by the method of direct recall. It has been demonstrated experimentally that although a subject is totally unable to recall any part of a previously learned material after an interval of forgetting, he will be able to relearn this material in fewer repetitions than it took him in the first place. Thus in this situation the subject can demonstrate a saving, which will give a positive score of the amount remembered by the savings method, while the score of the amount remembered by the method of recall would have been zero. The reason for this difference is that the method of recall measures only those associative bonds which have a strength sufficiently great to be above the *threshold of recall.* On the other hand, the savings method measures the strength of all associative bonds, both those above the threshold of recall and those below this threshold. These latter are associative bonds whose strength is not great enough for actual reproduction but whose existence may be demonstrated by the relearning procedure of testing the amount remembered and the amount forgotten.

The procedure for this experiment, then was as follows. The investigator had lists of nonsense syllables prepared by someone else and he himself acted as the only subject in the experiment. He learned many lists of 12 nonsense syllables, visually presented, each to the point of first errorless anticipation, and after the different intervals of time, he relearned these same lists with the same criterion of learning in mind, thus testing the amount forgotten by the saving method. And it will be remembered that the saving method gives a more advantageous score than the method of simple recall.

The results which he obtained, expressed in terms of the per cent forgotten, are given below:

Time interval	*Per cent forgotten*
20 minutes	42
1 hour	56
8 hours	64
1 day	66
2 days	72
6 days	75
30 days	79
120 days	97

For convenience the results for the first six days have been made into the curve reproduced (fig. 67). The results for 30 and 120 days are left out of this curve inasmuch as the results for the 20 minute and 1 hour periods would be too crowded toward the left hand side to be legible. In this chart, on the bottom horizontal line (called the *abscissa*) are laid off the different intervals of time between learning and relearning. The heights of the curve above these points on the abscissa (called the *ordinates*) indicate the amounts forgotten after the different intervals, each being derived from averages of a large number of trials.

The form of this curve is entirely characteristic of all curves of the rate of forgetting. It rises very rapidly at first, indicating rapid initial forgetting, and then continues to rise but more and more slowly. An examination of the figures in the table indicates that well over half of the material has been forgotten after an hour and that three-fourths has been forgotten after six days. This would seem to be a very distressing state of affairs, that one may only expect to remember half the learned material within an hour and less than a fourth of the material a week after you have learned it. This is indeed a discouraging outlook for both pupil and teacher. And there can be no doubt of the correctness of these results under the condition of the experiments. Indeed these results become more discouraging when one remembers that they were obtained by the advantageous saving method.

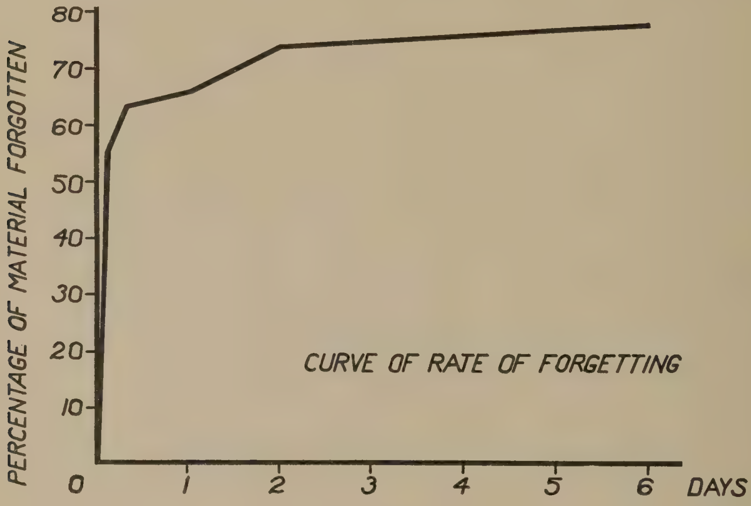

FIG. 67

It is possible to look at these results, however, from another point of view. Examine the results in the table for the 120 day period and you will find that approximately a 3 per cent saving was effected in relearning even after this interval. It seems surprising that any saving can be demonstrated after a four month interval, in relearning a list of nonsense syllables. One would have thought that by this time all of this sort of material would have been entirely forgotten.

But still this very rapid rate of forgetting must seem discouraging and there are many who will insist that such a rapid rate of forgetting is not true or characteristic of their own case. How then can we account for these results? The criticism can be raised that there was only one subject, the investigator himself, in this experiment and that he must have had a very poor memory. But the experiment has been repeated a large number of times under these same conditions with a large number of different subjects and the results are always more or less the same. The rise of the curve is somewhat less rapid for some subjects but even somewhat more rapid for others. This observer happened to have about an average rate of forgetting and hence this criticism of the results is not valid and will not account for the rapid forgetting.

Another criticism may be raised that these results may be true for unusual material, such as the nonsense syllables employed in this experiment, but that forgetting would be much slower for ordinary meaningful material. These experiments have been repeated using such meaningful materials as prose and poetry and it was found, if the other conditions of the experiment remained constant, that the forgetting rate for the shorter intervals of time is not quite so rapid as it is for nonsense syllables, but that the curves for meaningful and nonsense materials are entirely similar after the first several days.

This discouragingly rapid rate of forgetting, as demonstrated by those results, is to be explained however by one of the conditions of the experiment. It is due to the fact that the material was only learned to the point of first errorless anticipation. If anyone will just learn some material and no more, he will find that 40 per cent will be lost after 20 minutes and that nearly 80 per cent will be lost after a month even if tested by the advantageous saving method, and he may be sure that much more will appear to have been forgotten if tested by the method of recall.

How frequently does a pupil in school say to himself after a first errorless repetition of a material: "Well, I have that learned now" and so stop the studying of the material. Under these circumstances, he will find when he tries to recite 8 hours later that almost two-thirds of the material has been forgotten. For more permanent retention, the thing which is required is *overlearning*; that is, one must continue to repeat the material after it has been learned. Experimental results indicate that overlearning slows up the rate of forgetting very considerably. if a given material is only slightly overlearned, the curve of forgetting will rise only slightly less sharply, but this will be true for all time intervals between learning and relearning. If the material is still more overlearned, the curve will rise still less rapidly. If there has been enough overlearning, one may reach the point at which there is no forgetting at all. When tested after an interval of time such extremely overlearned material is as efficiently relearned or even recalled as it ever was. There is no forgetting and hence the curve never leaves the abscissa. In his youth, the author very completely overlearned a long poem, for reasons unknown or forgotten. He has only occasionally tried to recall this poem in recent years and he finds that there seems to be no decrease whatsoever in his ability to do so. The extreme overlearning in this case has meant that there has not been any forgetting at all even as measured by the less adequate method of recall.

There are many experimental results which show that a relatively small amount of overlearning brings big returns in delaying the speed of forgetting. These results indicate that in many cases 50 per cent overlearning is sufficient to change markedly the steepness of the forgetting curve. Hence, if you find that it takes 8 repetitions to just learn a material, if you will then spend the time for 4 additional repetitions (a 50 per cent overlearning), you will find that subsequent recall or relearning will be markedly improved over the condition if you had stopped when the material was only just learned and no more.

It is of interest to say a few words regarding the accuracy and reliability of memory. This problem becomes important for the psychology of testimony as it is given in a court of law. Very frequently memories turn out to be highly inaccurate and unreliable in such a situation. This is not surprising when one considers, in the first place, that forgetting consists in the complete dropping out of the part images of a recalled previous complex perceptual experience. Besides this, normal forgetting is favored by the great delay usual in present day court procedure in America. When one considers the normal rate of forgetting, which has just been discussed, it is really rather surprising that witnesses are able to give as accurate and as detailed testimony as they do. Sometimes a year or more may elapse between the time of a perceived incident and the the time when the case comes up for trial; and the witness is expected to recall and describe in detail exactly what happened a year before, usually only on the basis of a single stimulation. Under these circumstances who can blame the lawyer who obtains a detailed statement from the witness at once while the perception of the incident is fresh in his consciousness and before much forgetting has taken place and then coaches this witness from the former detailed statement at the time of the trial just before he goes on the stand to give his testimony. A knowledge of this unreliability of memories after a long interval of time is utilized by opposing trial lawyers. If the opposing lawyer can get the witness to accept the filling in of some forgotten detail with what he suggests and if he can then prove that this admission on the part of the witness is untrue, he will have gone a long way toward discrediting all of the testimony of this witness. On the other hand, if the witness successfully resists such suggested filling in of forgotten details and truthfully answers "I do not remember" too frequently, the opposing lawyer may again go a long way toward discrediting all of this witness' testimony on this basis.

It has been said above that a detailed description of the factors of efficient or economical learning more properly belong in a text of educational psychology than in the present place. The curve of learning will be described later in a description of some aspects of motor learning in the treatment of habit formation. One aspect of learning as related to efficiency of recall, however, has been widely treated in recent expositions of memory and should at least be mentioned. It has been discovered that the efficiency of the recall of a learned material is greatly affected by the conscious activity, and especially by other learning, between the original learning and the subsequent recall. This fact has been called *retroactive inhibition* because the other activity following learning has an inhibitive effect in reducing the ability to recall, retroactively, upon the material previously learned. Some psychologists have indeed considered retroactive inhibition as the primary cause of all forgetting. From this point of view, forgetting is conceived as a much more active process than it was before. Formerly forgetting, indicated by the gradually diminished ability to recall, was conceived in terms of the gradual decrease of the modification of brain areas with the passage of time and of the gradual weakening of the associative pathways connecting brain areas. If one accepts the principle of retroactive inhibition this process of the decrease in modification of brain areas and of the strength of associative pathways is a function of the active interference of the new modification of brain areas and the establishment of new pathways due to subsequent learning. There are some very interesting experiments on the interpolation of learning and rest periods between learning and the recall of the learned material which indicate that retroactive inhibition plays a part, at least, in all normal forgetting. One of the most striking of these experiments shows a significantly smaller amount of forgetting when the period between learning and recall is spent in sleep (when there is little or no other mental activity to inhibit or interfere with what has been learned) than when this period is filled with waking concentrated mental activity. The rate of forgetting during sleep, when there is little or no retroactive inhibition, is much less rapid than during the waking life, when the effects of retroactive inhibition are more or less sure to be present. Probably the truth is that the factors of the normal loss of modification by disuse and by retroactive inhibition are both important for a complete understanding of normal forgetting.

In this chapter then, it has been found that there are two sorts of memory; perseveration, which is a sort of memory after-image of short duration, and logical memory which insures much greater retention. The difference between these two sorts of memory is to be explained in terms of the presence of associations in logical memory which are lacking in the simpler perseveration. Association is a principle of explanation which indicates that if ideas are experienced together they are apt to be recalled together. This is best explained in terms of the establishment of pathways of discharge between modified brain areas. Emphasis is thereby given to the fact that one's associations are as much dependent upon one's own past experience as we have found the individual memories themselves to be. Thus the important problem for memory is really that of recall. In physiological terms this problem requires an explanation of how one may get nerve energy into a particular modified brain area so that a particular idea may come to consciousness. Efficiency of recall is accomplished, first, by the existence of a large number of associations so that there exist many pathways by which nerve energy may get from one brain area to another, and secondly, by having these pathways so well established that the nerve energy may pass with great facility from one area to another. Some of the factors affecting the strength of such associative bonds are the recency, emotional congruity and vividness of the original experience. Perhaps even more important than these is the principle of repetition. The results indicate that forgetting, the inability to recall, is very rapid if the material is just learned. Permanent retention normally requires a considerable amount of overlearning.

QUESTIONS

1. How can perseveration be distinguished from logical memory?
2. What is the major classification of problems in logical memory?
3. What explanation is given to account for recall?
4. How are the Primary and Secondary Laws of Association related?
5. What is the Physiological Explanation of Association?
6. What is the contribution of the nonsense syllable to our study of the psychology of memory?
7. At what rate does forgetting progress? How was this curve determined?
8. What can be done about slowing up the rapid rate of forgetting?
9. What significance does the psychology of memory have for the psychology of testimony?
10. What significance does retroactive inhibition have for the problem of forgetting?

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CHAPTER XIII

THINKING

A treatment of the problems of *thinking* cannot be better initiated than by asking the reader to think. This can be accomplished by the reader's solving a few problems which will be given below. These problems are perfectly straightforward and none of them contain a "catch" or trick of any sort. Each problem can be solved by proper and straight thinking.

The first problem has to do with a transaction in a shoe store, and for the sake of simplification, we shall consider that it is a cost-price sale,—the pair of shoes to be sold cost the dealer exactly what he is getting for them. A customer enters the shoe store and selects a $7.00 pair of shoes. He hands the shoe dealer a $10 bill which the dealer is unable to change. So the shoe dealer goes to the grocery store next door and gets ten $1 bills for the $10 bill. He hands the customer the shoes and the $3 change and the customer does not appear again in the problem. Shortly after, the grocer comes in and shows the shoe dealer that he has given him a counterfeit $10 bill. So the shoe dealer gives the grocer two good $5 bills which he had in his till and tears up the counterfeit $10 bill. Who is the loser and how much?

May the reader be reminded that this is a chapter on thinking. This should indicate that he is to think his way through this problem and not to give a mere snap judgment regarding the answer. It has been the author's experience, when this problem is presented to a large class of college age, that one obtains a variety of answers ranging all the way from a loss of $3 to one of $37 on the part of the shoe dealer. It is seldom that anyone except the shoe dealer is considered the loser.

If the reader has obtained an answer different from $10 (or $3 and the shoes) he should read the problem again and do some more thinking because $10 is the correct answer. If he still persists in a solution other than $10, let him raise the following question: "Who is ahead and how much?" It has been found that subjects almost always say at once that the customer is the gainer by $10. Certainly, no one involved in this problem can lose more or less than someone else gained.

Try another problem. This involves a train going from New York to San Francisco, and in the interests of simplification, disregard the fact that there are time differences between these two cities. Here is the problem. A train schedule, which has been in operation for many years, calls for a train to leave New York for San Francisco exactly at 12 noon daily and Sunday. At exactly the same time, 12 noon, each day and Sunday a train leaves San Francisco for New York. It takes exactly 7 days to make the trip in either direction,—the train leaving New York reaches San Francisco at exactly 12 noon seven days later and vice versa. Remember that the schedule has been running for some years. Now, a given train leaves New York. How many San Francisco to New York trains will it meet before it reaches its destination?

This problem always gives a variety of answers and it is not often correctly solved. Either of two answers would be acceptable as correct depending upon whether one counts the train which pulls into New York just as the New York-San Francisco train leaves and also the train which pulls out of San Francisco just as our train pulls into the station at that city. Hence the correct answers are that our train meets 15 trains going in the other direction, if one counts those at the two ends of the trip, and 13 trains, if one does not count them.

Even though the reader has been given the correct answer, experience in many cases shows that it is necessary to demonstrate how that answer can be correct. Let us indicate a simple solution. Let us say that our train pulls out of New York on the 8th of a given month. Just as it pulls out, it will meet the San Francisco to New York train which left San Francisco on the 1st of that month,—seven days before. Our train leaving on the 8th will get into San Francisco on the 15th, seven days later, and will meet the train leaving that city for New York on that date. As it leaves New York, our train met the train which pulled out of San Francisco on the 1st and when it arrives at San Francisco it will meet the train which is pulling out on the 15th. And on the way, it will have met all of the trains which pulled out from San Francisco on the 2nd, 3rd and up to the 14th. It will have met 13 trains en route and one train at each end of the journey or 15 trains in all.

If the reader is interested in problems which can be solved by straight thinking, let him try the following. The correct solution will not be given but the reader is assured that the problem can be solved. It is a problem in long division in which it is indicated only that there is no remainder and that the third digit of the quotient is 8. The problem is to fill in the missing numbers.

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To start off the reader in the solution of this problem, one may point out the first step in the solution. It will be observed that there are five digits in the quotient while the division is completed in only three steps. It will also be noted that in the second step it is necessary to bring two digits down from the dividend. This means that the bringing of the first digit from the dividend produced a number, at this point, which was smaller than the divisor. Otherwise it would not have been necessary to bring down the second digit from the dividend.

Hence the second digit in the quotient must be zero and thus the first step in the solution is to place a zero in the quotient just before the 8 already there. With this hint regarding the kind of straight-forward thinking required in the solution of the problem, the reader is left to complete the solution.

By now a number of readers will probably have protested that all of these three problems are mathematical in nature and some readers at least will say that they are not mathematically inclined. Therefore another more concrete type of problem is presented. Look at figure 68. The problem is to draw this figure with a single series of continuous straight lines without taking your pencil from the paper and without going over a line a second time. It is, of course, permitted to draw a line which crosses another line at any angle. The reader is again reminded that this is a chapter on thinking.

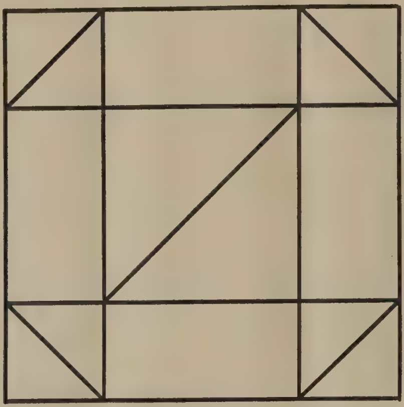

FIG. 68

Experience indicates that most individuals, even at the college level, go about the solution of this problem just about the way a rat would go about finding his way in a maze. They select, more or less by chance, a place at which to start and then proceed until they find that this line of attack will not bring success. Then they start at some other point and try again. This sort of procedure has been called the *trial and error method.* And the human has this advantage over the rat. He may see the ground plan of the entire figure and hence can foresee failure of a given line of attack without carrying through the trial to its unsuccessful end. Sometimes subjects succeed in solving this problem on the first trial. They start at the right place. But, if the reader has been successful in solving the problem in the first trial, he will surely admit that he did not have any really good reason for starting where he did. His success was more or less a matter of luck in starting at the right place.

Had the reader stopped to think before attempting the solution of the problem, he would have discovered, as can be seen in the solution below, that there are two places (marked 1 and 2) in the figure where 5 lines come together. All other places in the figure have fewer than 5 lines coming together. Thinking would indicate that one must begin at a point where the most lines come together; otherwise it will not be possible to get back to this point at the end of the solution. Thinking would therefore have shown that you had to begin at either points 1 or 2. If this principle is recognized, from then on one will find that there are a large number of solutions of the problem,—the route one takes from the starting point is more or less immaterial. One possible solution is indicated in figure 69. The path can be traced by starting at 1 and following the direction of the arrows to each number successively through 15 and finally ending by returning to 2.

It is hoped that these several problems will have demonstrated two things. In the first place, thinking may save a great amount of time and energy. In the last problem, had the reader stopped and thought so that he recognized the single simple underlying principle of the problem, he might have saved himself much time and labor in the making of unnecessary and unsuccessful trials. But it has been observed that most humans, and even highly intelligent individuals, do not think in many situations until after a certain amount of trial and error procedure has failed to bring success. All too frequently thinking occurs only when the individual is forced to think because of the failure of other methods to bring a successful solution of his problem.

The second thing which it is hoped that these problems will have emphasized is that there is much less real thinking going on in the world than many of us believe. Much that passes for thinking is really pseudo-thinking and this is largely merely a memory recall of some past experience which seems to fit the solution of a particular problem of the moment. One does not usually go to a popular novel for technical psychological quotations. But in a novel of some years ago, there appeared a sentence which indicates a psychological insight of the profoundest sort. In describing one of his characters, the author said that she had "far too good a memory ever to have an original thought." This character was conceived as an individual with such a fund of past experience that some image of past experience could be recalled, very frequently at

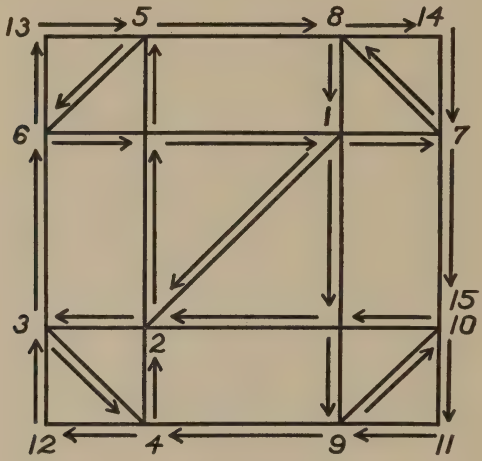

Fig. 69

least, for the solution of any problem which might confront her. Thinking, at this level, became more or less unnecessary.

The reader will now be asked to think in a manner controlled by the text. If possible, because of the reader's imaginal type, he is asked to think in terms of visual concrete images. If possible, therefore, will the reader call up a visual concrete image of a dragon. In this image notice the form and color. The color should be green and the skin should be covered with scales. If these features are not part of the image, will the reader place them there. Once you have succeeded in having your image of the dragon in this way, put some orange spots on the surface of your imaginary dragon. Be sure that flame is coming out of the mouth and smoke out of the nostrils of your dragon. If you have succeeded in constructing this idea, it can be ventured that this is a new idea in your own experience. It seems almost certain that you have never had an idea of a dragon exactly like this one. In other words, this is a new thought different from anything you have ever had in your own past experience.

But what is new about this experience? The form is not new,—you have seen lizards or pictures of lizards or of dragons before. The color green or the scales or the orange spots are not new. Certainly each reader will have had all of these in his past experience. The flame and the smoke or any of the other details of this new image all have a perceptual background in one's own past experience. The only thing which is new in this so-called new thought or idea is that there is a new grouping of perfectly familiar old ideas. It is the grouping which is new and not the ideas which are grouped. Thinking may be defined as the presence in consciousness of a configuration of old ideas in a pattern different from that in which they were experienced. Thus there are both similarities and differences between thinking and remembering. In both cases, the conscious content is the image, based upon previous individual past perceptual experience. But in remembering, these images, because of association, come to consciousness in the same pattern in which they were experienced, while in thinking, the conscious pattern of these old images is different from that in which they were experienced. There is nothing mysterious about the problem of thinking if it is considered merely as the rearrangement in a new way of old images of experience.

Thinking may vary in several ways. It varies according to whether the images to be arranged in a new way are primarily concrete or verbal. Several chapters ago, in the discussion of amnesia and aphasia, it was seen that the distinction between concrete and verbal images had a real psychological basis. And thinking may also vary if the rearrangement of old images in a new way is directed or not directed,—if the rearrangement seems to be more or less haphazard, on the one hand, or if it seems to be in accordance with a plan on the other. We shall have much more to say about this matter of direction later in this chapter.

It is possible therefore to differentiate four kinds of thinking which are summarized below:

	Not directed	*Directed*
Concrete images......................	Fancy	Creative Imagination
Verbal images........................	Revery	Reasoning

These four kinds of thinking are all similar insofar as all consist merely in the presence of old images in a configuration different from that in which they were experienced. *Fancy* consists in the new arrangement of concrete images without direction; while *revery* is the undirected rearrangement in a new way of verbal images. On the other hand, *creative imagination* utilizes old concrete images but the rearrangement, in the new pattern, is under direction. *Reasoning* is the directed rearrangement of verbal images in a new constellation or a new configuration different from that in which they were experienced.

Possibly the best examples of fancy and revery are to be found in what has been called "day dreaming,"—the building of "castles in Spain," but even better and more frequent examples are to be found in actual *dreams*. Very frequently in dreams during sleep, we have a rearrangement of old images in a new way but this rearrangement seems to be more or less haphazard and frequently fantastic. Seldom can one find any real direction in the arrangement of these images. If one includes dreams as examples of thinking,—and they fit the definitions of undirected thinking in every particular, there may be much more thinking going on in the world than we imagine. Whether there is more or less thinking depends upon the definition of the term.

In creative imagination and reasoning, however, the directed ordering of the new arrangement of images is apparent. It is direction toward an end, toward the solution of some problem. The artist is attempting to express some symbolic idea when he paints a picture. The engineer is solving a problem when he designs a locomotive. In both cases there is direction; in both cases there is a new arrangement of parts, and in both cases all of the parts which are rearranged are images based upon past perceptual experience. Psychologically the artist when he paints a picture and the engineer when he designs a locomotive are using the same kind of conscious process. Truly the goal which they are trying to reach is different and equally truly the particular images which they are rearranging each to solve his problem are different. But in both cases the psychological process consists in the rearranging of old concrete images in a new configuration and thus, in both cases, the essential psychological process is the form of thinking which has been called creative imagination.

Similarly the thinking of the poet, when he composes a poem, and that of the philosopher, when he writes a paper on the nature of the atom, are entirely similar in so far as the type of psychological process is concerned. The thinking of the poet and of the philosopher is essentially reasoning, inasmuch as in both cases, it consists of a rearranging of old verbal images in a way different from that in which they were experienced. But in both cases this process is directed toward the solution of some problem. The only differences between the thinking of the philosopher and the poet is in the type of problem which directs the thinking and in the particular verbal images which they may employ.

Let us hasten to add that these sorts of thinking are not to be considered as existing in separate mental compartments. In one's normal life, there is a great deal of overlap among the four forms of thinking. It is seldom that one rearranges in a new configuration only verbal images with no concrete images at all or only concrete images without verbal participation. It is seldom, and this is certainly true in a long thinking process, that this rearrangement is entirely without direction or that it is completely directed throughout. It is seldom, therefore, that one finds in experience pure examples of revery or reasoning; of fancy or creative imagination. It is equally true that there is a degree of overlap between remembering and thinking. In the normal process of remembering, we have already discovered that the complete dropping out of details of part images is a universal and characteristic experience of forgetting. If you will examine your recall of some partly forgotten experience, you will find that part of this process involves an active attempt to fill in, to supply with other images, some of the details which have been forgotten. Such an active attempt to reconstruct the forgotten parts of a recalled experience is essentially an example of directed thinking. Such an incomplete recall may lead to reasoning or to creative imagination depending on whether one employs primarily verbal or concrete images. Bnt, in any case, this attempt to reconstruct the partly forgotten experience is definitely directed.

In the history of the problem of thinking it has often been said that the logical *syllogism* represents the highest form of reasoning. It has been said that a syllogism, which is a proposition stated in the form of two premises and a conclusion is the apex of thought, as for example:

All men are mortal
Aristotle was a man
Therefore, Aristotle was mortal

The psychologists would insist that the logical syllogism is not a way of thinking at all but merely an ideal way of expressing one's ideational configurations after one has thought them through, particularly well designed to test the truth or falsity of the new arrangement of ideas. In normal life we do not think in the following way:

I want to get down town as rapidly as possible
The bus is the most rapid means of transportation available
Therefore, I shall take a bus to do down town

By no means does one ever think in the logical form of the syllogism. You say to yourself: "I'm in a hurry to get down town" and you find yourself headed for the nearest bus stop. If there is anything which has been firmly established by the experimental psychology of thought, it is the fact that *thinking is not carried on in logical terms*, no matter how well logic may be equipped to test the validity of the *results* of thought processes.

Much has been written regarding the so-called *higher mental processes*. Many kinds of processes have been listed under this category from time to time, such as comparing, judgment, abstraction, generalizing and volitional choice as well as reasoning and creative imagination. This list is by no means exhaustive of the kinds of higher mental processes which have been suggested in the psychological literature. Psychologically, all of these mental processes become merely forms of thinking, as thinking has been treated in the present text. One can consider all of these different kinds of higher mental processes as forms of thinking because each involves only the reorganization of old images of past experience in a configuration different from that in which they were experienced. And the only difference between these kinds of higher mental processes, between comparing and abstraction for example, is to be found in the particular *pattern* of the new arrangement of the old images.

One can emphasize this fact by relating an incident in the author's experience. Some years ago, a number of experimental problems were in progress, in a certain psychological laboratory, each concerned with the analysis and description of a particular higher mental process. The experiments had to do with logical memory, comparing, judgment, abstraction, generalization, volitional choice and recognizing. Each investigator was also acting as subject in all of the other experiments. One day the laboratory director had all of the investigators in his office for a conference. We all insisted that there was no doubt that each of these kinds of mental process was different from all of the others. One could tell, when he went in to one experiment, that he was abstracting, and in another, that he was comparing. Each investigator insisted that the reports of subjects in his experiment indicated that the mental content of his particular process under investigation was restricted to perceptual and imaginal experiences solely. But each investigator also insisted that, for his experiment and for the kind of mental process which he was investigating, the experimental results showed that the *pattern* of the rearrangement of these perceptions and images in consciousness was different from the pattern of each of the other higher mental processes under investigation.

The description of each of these different patterns is too complicated and leads to a too technical description for inclusion in the present text. How complicated the situation becomes may be imagined when it is pointed out that the conscious pattern varies, not only for the kind of higher mental process, but also for the imaginal type of the person who is doing the thinking. Thus abstracting for an individual of visual concrete type would be a very different conscious pattern than would abstracting by an individual of kinesthetic concrete type. And the matter is still more complicated by variations in conscious pattern for different degrees of habituation of the process, even for the same observer and for the same higher mental process. For example, it is obvious that the conscious pattern for recognizing would be different, even for the same individual, if the recognition was long and difficult and dealt with a practically unfamiliar object or if the recognition was of a very familiar object. For example, the recognition of one's closest friend gives a very different conscious pattern from the recognition of some one whom one meets who seems familiar but whom one cannot quite place. The situation is indeed complicated when one considers that this conscious pattern of the rearrangement of old ideas in a new way may vary for the kind of mental process, for the imaginal type of the person thinking, and for the degree of habituation of the particular process for that particular individual. But the results show that it is possible to give an adequate description of the conscious pattern for abstracting by a person of visual concrete type in the later or habituated states of this process. And, on the other hand, it is possible to give an adequate description of the conscious pattern for comparing by a person of kinesthetic verbal type before great habituation.

Recent experimental results indicate that thinking may be a slow process extending over a long period of time but that the solution of the problem often comes in a flash and may be instantly recognized. The term *insight* has been given to this sudden recognition of a correct solution in thinking. One may illustrate this principle by asking the reader to solve the following problem given in figure 70. The circle is divided by two diameters AB and DE at right angles to each other. Each diameter has a length of 10 units. A point G is marked off on the verticle diameter 2 units above the center of the circle C. A line is then drawn from this point G to the circumference of the circle at F which will be parallel to the diameter DE. A perpendicular is dropped from F to the diameter DE which will strike this line at the point H. Hence there has been constructed a right angled quadrilateral FHCG. The problem to be solved is to determine the length of the diagonal HG in this quadrilateral figure. Those of you who are mathematically inclined might spend hours in the attempted solution of this problem by geometry. You may know that HG^2 is equal to the sum of GC^2 plus HC^2. But, unfortunately, only the length of CG is given and there seems to be no means of determining the length of the line CH, which it must be realized does not reach to the circumference of the circle. The solution is accomplished only when one realizes that the diagonal CF must equal the diagonal HG, inasmuch as the figure FHCG is a right angled quadrilateral. Then it must be realized that the diagonal FC is also a radius of the circle. At once, in a flash, the solution to the problem is obvious. One has obtained insight and the solution is there fully formed.

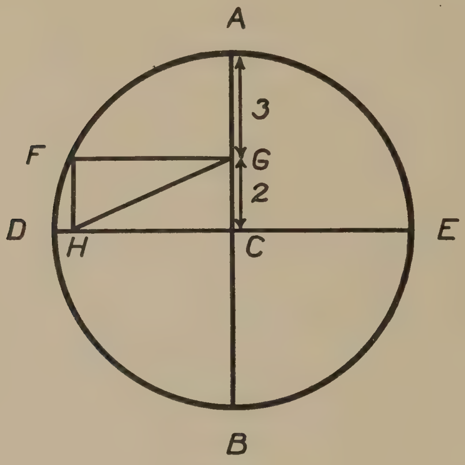

Fig. 70

Such a point of view toward thinking emphasizes that this process is merely the rearrangement of old ideas in a new way,—in a different pattern from that in which they were experienced. Thinking consists in a series of such rearrangements until finally the elements in consciousness fall into a particular pattern which is recognized as giving a successful solution of the problem. Insight is the acceptance or recognition of this particular conscious pattern as one which has successfully solved the problem.

There is experimental evidence which indicates that insight as an essential feature of thinking is not confined to human thinking only. We have reason to believe that there is insight present in successful solutions of problems presented to the higher apes, such as the chimpanzee, and even in animals as low in the animal scale as the rat. If the presence of insight is a criterion of the existence of thinking, these results disprove the commonly accepted popular idea that thinking is a possession of humans alone and is denied to the lower animals.

A recent experiment consisted of giving reasoning problems to a large number of students. These were divided into two groups. The first group of students were given a lecture, before they tried to solve the problems, in which insight in thinking was explained. In this lecture it was explained that the successful solution would appear rapidly, that the solution of a problem consists of a pattern which is made up of parts of different past-experiences and that the solution overcomes a difficulty which must be recognized. Finally it was emphasized that if an attempted solution is unsuccessful it is wise to drop it entirely and try some totally new configuration. In other words, it is impossible to force a certain solution if one finds at once that it will not be successful. This lecture to the first group lasted only 20 minutes. The second group did the same reasoning problems without the benefit of this lecture on the nature of thinking. The results indicate that the first group, after only a 20 minute lecture on the nature of insight and of thinking, showed a marked superiority in problem solving—that they were more than three times as efficient—over the other group who did not have the advantages of this analysis and description of the nature of thinking.

This investigator gives three simple rules for successful thinking. (1) First locate a difficulty and try to overcome it. If the attempted solution is not successful, get it completely out of your mind and seek some entirely new and different difficulty which the problem presents. (2) Do not stay in a rut and be a creature of habit. Keep your mind open for new problems, new difficulties and new solutions. (3) The solution pattern appears suddenly. You cannot force it. Be forever trying new combinations of past experience in new patterns and do not waste time on following up unsuccessful attempts.

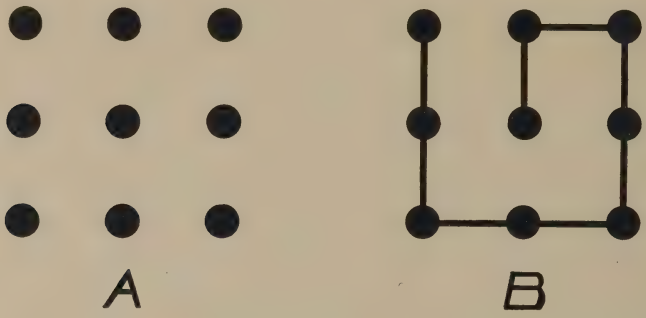

Fig. 71

We have indicated above the importance of direction for thinking and have used the notion of direction as a basis for differentiating creative imagination and reasoning from fancy and revery. The nature of this direction must be considered. The name *intention* has been given to this sort of direction in thinking. Intention is the reorganization of old experiences in a new way directed toward some *goal idea.* The goal idea is itself an image in consciousness. It is the idea which the poet wishes to express when he creates a poem; it is the problem which the engineer wants to solve when he plans a locomotive. Intention and goal idea thus become important for the problem of *motivation* which will be treated in a later chapter.

How important intention and goal idea may be can be determined by trying the solution of the following problem (fig. 71). Nine dots are arranged in the form of a square as in *A* in figure 71. The problem is to join these nine dots with a series of continuous straight lines without taking your pencil from the paper. It is easy to connect the 9 dots in the form of a square with a series of 5 straight lines. Such a solution, and there are many variations, will be found in *B* above. But the problem is to connect all of the 9 dots with a series of only 4 straight lines and not 5. The reader is asked to really try to solve this problem before he looks at the solution on page 244 (fig. 72). You will probably find that you do not hit upon any successful solution even though you think about the problem for a considerable time. But the reader is assured that there is not one, but a great many possible solutions of this figure.

The reason for your failure is because you set yourself a wrong intention,—a wrong intention which was fostered by the setting of the problem itself,—of staying within the limits of the square. The problem was set as 9 dots "arranged in the form of a square." The incorrect solution emphasized the boundaries of the square. But if you will look back at the instructions you will find that there is no mention whatsoever compelling one to stay within the area of the square in the solution of the problem. Only when one sets himself a new intention which allows him to go outside of the boundaries of the square can the solution of this problem be accomplished.

Try another problem (fig. 73). Take 11 match sticks and arrange them in the form of the following problem which is written in Roman numerals. The problem is to move only one match and produce a true mathematical equation. Try this problem before you look at the solution on the next page.

Undoubtedly you will try to move the isolated matches in the IV and the VI to try and obtain an equation which is mathematically correct. You will find that you will not be successful

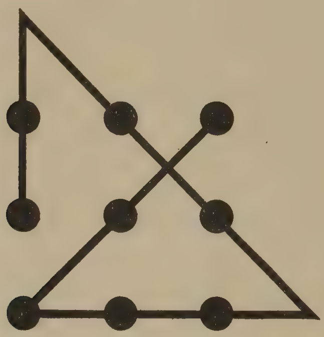

FIG. 72

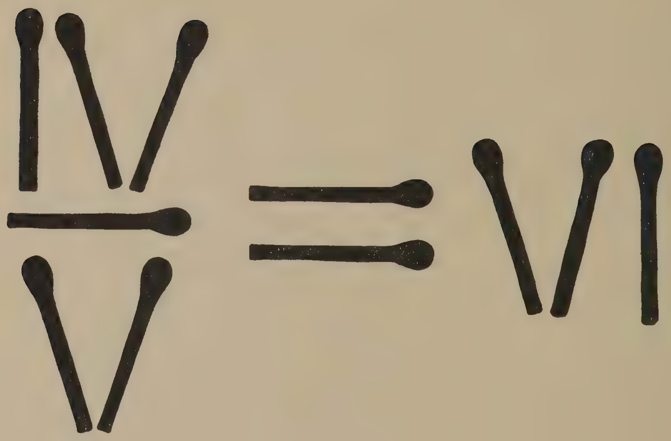

FIG. 73

in this type of solution. The problem can be solved only if one changes his intention from an attempted solution in terms of simple arithmetic to one involving the use of mathematical symbols. Then the solution given below becomes apparent (fig. 74). Five divided by five equals the square root of one is a true equation because both sides of this equal one.

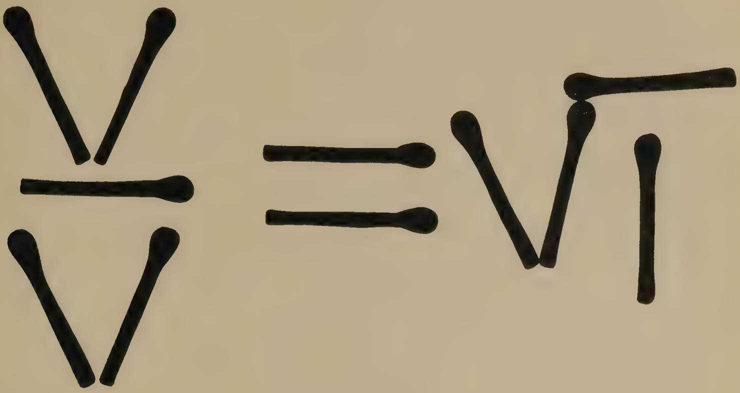

FIG. 74

Let us try one more problem for solution which consists in doing the following simple crossword puzzle (fig. 75) which contains only 16 squares:

1	2	3	4
2			
3			
4			

FIG. 75

Down	*Across*
1. Insects	1. What dogs do
2. Organs of vision	2. What cats do
3. Vex	3. What lions do
4. Comfort	4. What humans do

One can predict that the solution of this problem will be exceptionally difficult for the habitual crossword puzzle enthusiast. He will be able to think of a great many four letter words which are adequate for the filling of any row either downwards or across. But he will probably be unable to make any of these words interlock with one another. The solution can not be accomplished until he rids himself of the usual intention of looking for different words for each row,—a procedure which is at variance with the usual crossword puzzle procedure. Dogs BITE, so do cats and lions and so even do humans on occasion. If the same word bite is inserted in the space for each of the across words, one will find that the down columns successively read Bs, Is, Ts, and Es which fulfill the downward requirements in every case.

This example has been included to emphasize how frequently, through habituation, a goal idea need no longer remain highly conscious in order to still have its directive influence on the reorganization of old ideas for thinking. But one can be sure that such a goal idea, which due to repetition has sunk near the conscious threshold, was once highly conscious. The habitual and no longer highly conscious goal ideas should be considered as the basis of what have been called *attitudes.* An attitude, which is always directional or intentional in character, is merely a goal idea which was once highly and clearly conscious but which, because of repetition and habituation, has lost in clearness and so has sunk close to the level of the conscious threshold. But in spite of this lack of clearness, it can be demonstrated that the attitude has maintained its efficiency for the direction of the form of new conscious patterns in thinking.

It should be pointed out that intention is not only effective in thinking but it is also important in simple association as well. If you are given instructions which say that you will be given a stimulus word and you are to think of the name of a railroad and then the name of your home town is given as the stimulus word, the first reaction word in consciousness will be the name of a railroad connected with your city. If you are now told that you will be given a stimulus word and you are to think of the name of a mayor or an industry or an educational institution, and the same name of your city is given as the stimulus word, your first reaction word will be different from that which you had before. This is a demonstration of the fact that your acceptance of instructions imposes upon you an intention which partially determines which of several associative bonds will become effective between the stimulus word and the several possible reaction words. The presence of a particular reaction word in consciousness, therefore, is partly determined by the relative strength of the several possible associative bonds but also by the intention present at the moment when the first idea is in consciousness. And there are experimental results which indicate that this sort of *directed association* is more rapid than the so-called *free association* in which there is no direction. It has been found that less time elapses between the appearance of the stimulus word and the reaction word in consciousness if the association is directed by intention. It will take longer to get a reaction word to a given stimulus word if the instructions are of the form "I shall give you a stimulus word and I want you to note the first word in consciousness afterward" than for the instructions "I shall give you a stimulus word and want you to think of the whole of which the stimulus word is a part." This difference in speed is accomplished in spite of the fact that, in the case of directed association, the second member of the pair will be a single particular word while, in the case of free association any word in the dictionary might be available.

From a consideration of these facts, one may get a hint of the possible physiological explanation of intention, although no complete physiological explanation has as yet been advanced which can be accepted as an adequate basis for intention.

Associative bonds have been explained physiologically as pathways of discharge between modified brain areas. It has been emphasized that these must be thought of as a series of constellations interlocking one with another. It would seem that intention lowers the resistance of a particular pathway of discharge. This fits the facts of the shorter time for associations in the presence of intention. Hence, if a brain area is stimulated in the presence of intention, then some of the excitation would go across the pathway of discharge whose resistance had been lowered by the presence of a goal idea rather than across any of the other possible pathways. Just how this lowering of the resistance of a particular pathway could be accomplished is a problem to which physiology cannot give a definite answer at present.

The matter would be fairly simple if we thought of it in terms of a single associative constellation. But the actual facts are very much more complicated than this. There is an attempt to illustrate the situation already discussed in the schematic diagram (fig. 76). In the left hand group of areas will be found the representation of the situation already discussed. The same repeated stimulus word is represented by the central area and the brain areas representing the different reaction words with pathways of discharge surround it. One may believe that the pathways of discharge between the central and the surrounding areas may have their resistance lowered, one after another, by intention. Hence the stimulation from the central area would cross the pathway of lowered resistance and would give successively the different reaction words dependent upon the different intentions set up by the different instructions.

However, if you are now instructed "I shall give you a stimulus word and I want you think of the name of a river" and then, as stimulus word, give the name of some other city, you would find that you would have the appropriate reaction word to this different stimulus word. And more than that. Experimental results indicate that this reaction word to a different stimulus word will appear in consciousness as rapidly as if the other stimulus word which had been used had been employed in this case as well. We are then faced with the complicated situation that the setting up of an intention by the acceptance of an instruction has lowered the resistance of the appropriate pathways of discharge in the second associative constellation as well as in the first, and presumably, in all other appropriate associative constellations as well. Physiology is certainly not prepared to explain such a complicated state of affairs and one can only say that an adequate physiological explanation of intention is not yet available. But one can be equally sure that future advances in physiology will eventually supply an adequate explanation of intention.

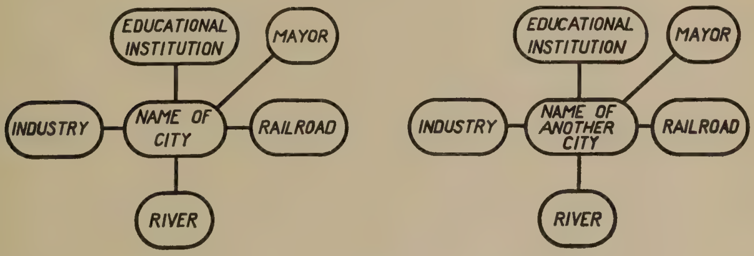

FIG. 76

One cannot leave the problem of thinking without returning again to the discussion of the problem of *meaning* as it appears in this connection. One realizes, of course, that in normal thinking one is concerned with the meaning and not usually with the particular images in consciousness. It is only when one becomes interested in psychology that he is concerned as to whether a given meaning is present in consciousness in terms of a visual concrete image or a kinesthetic verbal image.

Look at figure 77. What does it represent? What is its meaning? Probably this picture will be more or less meaningless for most readers. But what if you are told that it is a picture of a soldier going around a corner followed by his dog? Then the figure acquires a very complicated meaning indeed. The process has not changed. The figure is the same exactly as it was before but new meaning has been given to it. Look at the two illustrations (fig. 78). What do they represent? Obviously they are pictures not only of human faces, but indeed, of two human faces expressing the different emotions of joy and sorrow. These figures were drawn many years ago by a famous artist who tried to determine how simply he could depict such complicated meanings. Certainly these circles

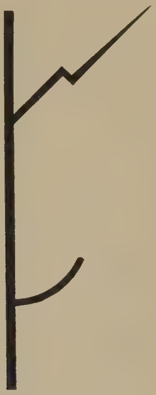

Fig. 77

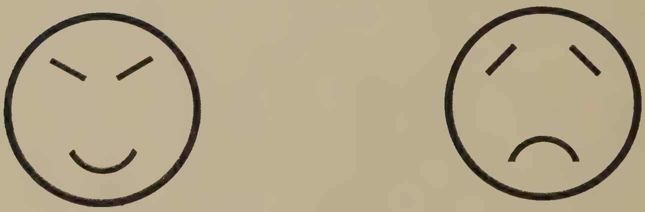

Fig. 78

each with three lines, comprise a very small amount of process for a very great deal of meaning. It is possible to depict the same meaning of two human faces expressing joy and sorrow, but with the faces in profile, as seen in figure 79. An examination of these very simple figures will reveal that each is composed of an ordinary bracket to which have been added only two short parallel lines. There can be no doubt that one may have a great deal of meaning, for thinking, with a very little mental content indeed.

The reverse is also true. One may have very little meaning with a great deal of content in consciousness. The author was recently in Europe and went one day to a restaurant where he was given a Polish menu and where he found that no waiter could speak anything but Polish. The author knows not a single word of Polish and one may be assured that during the attempted reading of the menu there was much in consciousness in the way of process with no meaning at all. Finally one word in the menu acquired meaning. This came quite suddenly, like all thinking, and his problem was solved. The word was "Rumsytzk" and he had rumpsteak for his dinner.

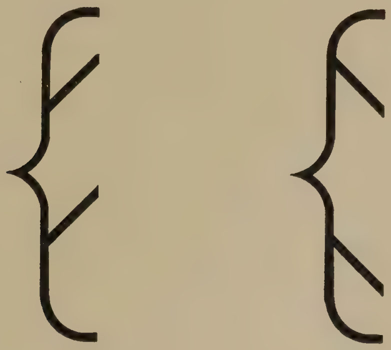

FIG. 79

Also any given process may have several meanings without any change in the content of consciousness. This fact is the basis for all puns. A particular pun seems worth repeating, because it is triple pun, even though it is presented better vocally than visually. It concerns a story of two young men, leaving their mother, and going west to seek their fortune. Eventually they write to the mother that they have finally become settled; that they have purchased a cattle ranch and expect to supply beef for the market. They write that everything is settled but that they want their mother to give them a name for ranch. She replies suggesting the name "Focus." They answer that it is a fine name but what does it mean. And the mother replies that "the focus is where the sun's rays meet."

Finally it is possible to change the mental content considerably without affecting or changing the meaning. This is what happens in normal forgetting when details or parts of a complicated memory image drop out, indicating a change in conscious content without any change in the meaning of the mutilated image. One can convince himself of this change in content without change in meaning by the following simple demonstration. Call up a visual image which has the meaning of "man." Now in your visual image begin to mutilate it. First cut off the arms, then the legs, then cut off the ears and gouge out the eyes of your concrete visual image. In spite of this mutilation you will find that it still has the meaning of "man." Now turn your mutilated image upside down so that it stands on its head and it still has the meaning of "man."

It has certainly been demonstrated that mental content and meaning are two independent variables. One can change either very considerably without affecting the other. One can have a great deal of either with very little of the other. And, in normal mental life, it is the meaning in which the individual is interested, not how these meanings are represented in consciousness by mental content. This is true for perception, for remembering and it is especially true for thinking. It is only when one becomes interested in psychology that he is concerned with the sorts of processes, such as sensations and images, which are present in consciousness, accompanying these meanings. And, important as the problem of meaning has proved to be, one must confess again (as we have previously confessed) that there exists today no adequate explanation of meaning nor any adequate psychological explanation of the relation of the conscious processes of sensation and image to meaning.

The discussion of the problem of meaning leads naturally to the consideration of *general ideas* or *concepts* about which a great deal has been written. Concepts or general ideas seem to be of several sorts. Call up your concept or general idea of "horse"; call up your general idea of "house." You may find that these concepts may be one of these three kinds. (1) It may be an image of some particular house which, somehow or other, has acquired the meaning of generality. How this meaning of generality is acquired by some particular image,—how the particular image comes to stand for the class of which it is a member,—is something which psychology cannot explain at present. But sometimes a particular image comes to represent the class of objects of which it is a member.

Or you may find: (2) that your concept does not represent any particular object of your past experience. Various parts may resemble parts of particular experiences but the total image is not entirely like any one of them. Psychologists have compared this sort of concept to a composite photograph. It is as if a number of impressions were superimposed on one another. In this case, the differences of the individual impressions will be blurred.

(3) The third way in which the concept may be represented in consciousness is simply by a verbal image. Your concept of the idea "house" may be simply a verbal image of the word "house." This representation of a concept in consciousness simply by a verbal image is particularly prevalent for *abstract ideas*. Your concept of "honor," "religion," "faith" and of

other abstract ideas usually has only the verbal image of the word as its conscious representative. It is quite possible that any of these abstract concepts may be represented in consciousness in concrete form. The idea of "honor" may be represented by a concrete visual image, for example, of an old man with a goatee and a slouch hat, typical of what we think of as a "southern gentleman." Or the idea of "faith" may be represented by a concrete visual image of a kneeling praying nun. Such concrete images for abstract ideas of this sort are purely symbolic images, and so far as their symbolism is concerned, they appear to be identical to the equally symbolic verbal images as representations in consciousness of abstract ideas.

A very interesting experiment has been performed to determine the stages found in the development of a new concept. An attempt was made to reproduce the sort of problem which confronts the biologist when he examines a number of specimens of some new animal through his microscope, and from this examination of individual specimens, emerges with a new concept which is expressed in his definition of the new species. In this case, the investigator prepared a number of drawings of an imaginary nonsense animal each showing similarities to and differences from all other drawings but with certain common elements throughout. All of the members of this series were given the same name and the subjects were told that they were all examples of the same species. The drawings were shown to the subject one at a time with many repetitions. In the development of the definition of the nonsense name and in the development of the concept underlying this definition, the following stages were passed through by all of the subjects. The first stage was one of mere observation of the figures. It was a stage of orientation to the material. A second stage was primarily concerned with a perception of differences in the figures. The third stage consisted primarily in an appreciation of likenesses and similarities between the individual figures.

The fourth and last stage was one of verification. This consisted in a directed or intentional perception of all of the figures to determine whether an apparently perceived similarity was universally present. From this fourth stage emerged the definition of the nonsense animal and the general idea or concept which was the basis of that definition.

This analysis and description of thinking brings to a close the treatment of conscious processes. There has been an attempt throughout to emphasize the fact that all conscious processes have their basis in the experience of the individual. This experience always involved originally some physical stimulus, external to the nervous system and acting upon it. This is obviously true of sensation where the physical external stimulus acts upon an end organ. We have found that there are at least 12 different kinds of sensation and that each sensory modality requires a very specific range of a very definite kind of physical stimulus acting upon its own particular kind of end organ.

We have proceeded in our description of conscious processes from sensation, the simplest sort, to reasoning, which is one of the more complex kinds of thinking. In all of these descriptions of conscious processes at different levels of complexity only two kinds of simple mental process has been mentioned, —sensation and image. And image has been found to be dependent upon some previous stimulation. The description of remembering and thinking have added two principles of explanation to the already discussed sensory and imaginal mental contents. These are association and intention. The principle of association explains how it is possible for two ideas, which have been experienced together in the past to recur together in consciousness at some later time. Association, therefore, becomes the basis for recall in remembering. The principle of intention explains how a consecutive train of thought is possible toward a certain goal idea. It explains really how a particular associative bond may be effective at any moment rather than other possible associative bonds. The principles of association and intention together give an explanation of all of the different kinds of thinking.

In the case of the two mental contents of sensation and image and the two principles of explanation, association and intention, there has been an attempt to explain each by an appeal to the physiology of the action of the nervous system. Sensation has its basis in the stimulation of nerve tissue and in the fact that there are direct nerve pathways from each sense organ to the brain. Image has its basis in the modification of brain tissue as the result of stimulation so that a restimulation of this modified area will result in an image in consciousness similar to the original experience. Association has its basis in the formation of pathways of discharge between modified brain areas. This explains how one may get nerve energy from one modified brain area to another by means of these pathways of discharge. Intention may be due, in some way, to the lowering of the resistance of particular pathways of discharge so that the nerve energy may pass across a particular pathway rather than over other possible pathways. But it must be frankly admitted that most of these explanations are at the level of physiological theory rather than of physiological fact. No one yet knows the nature of the modification of brain tissue for imagery; the nature and anatomical location of particular pathways of discharge for association and certainly not the nature of the lowering of resistance in these pathways for intention. For an adequate and complete description of all of these, we must wait for further advances in the accumulation of physiological fact.

But the treatment of conscious processes, from sensation to thinking, has been a consistent attempt to emphasize that there is nothing mysterious about any of them. Each kind of mental process, be it simple or exceedingly complex, is capable of description and analysis. And there has been an attempt to emphasize the continuity of mental processes from the simple to the complex. It is not possible to differentiate sharply between them. A given mental process may be remembering, at one moment, and thinking, at the next. It may be revery, at one moment, and reasoning, a moment later. The idea of separate "mental faculties" must be abandoned. The different kinds of mental processes are not separated from one another each in its own little compartment of mind. Instead it seems wise to substitute the concept of a hierarchy of mental processes in which each of the higher kinds are dependent upon all of the types which are more fundamental. In this hierarchy, the sensation and the perceptual experiences are basic for all others. In the second stage of the hierarchy, the image is dependent upon the basic sensation. Remembering—for the third stage of the hierarchy, is based upon image, but requires the explanatory principle of association for its complete description. And in the fourth and last stage of the hierarchy, the more complex types of thinking, such as creative imagination and reasoning, have their basis in image and association but also require the addition of the explanatory principle of intention for their complete description.

One last word before we leave the discussion of the problems of consciousness. We have found that no conscious process ever just happens spontaneously. Each requires some immediate external physical stimulation acting upon the nervous system to set them going. Be it sensation, remembering or thinking, some external stimulus must supply the energy which eventually stimulates some portion of the brain surface so that this stimulation will result in consciousness as sensation, image or a train of images as in thinking.

QUESTIONS

1. Is thinking as it is observed among people in general a logical process?
2. How is memory related to thinking?
3. How may thinking be differentiated into four types?
4. In what way do the thinking of the poet and the thinking of the engineer differ?

5. What distinguishes comparing from abstraction?
6. Give three rules for the successful solution of problems.
7. What relation does the goal idea bear to thinking?
8. How do attitudes develop?
9. How does the concept develop?

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PART IV. REACTION

CHAPTER XIV

REACTION—GENERAL—AND THE NERVOUS SYSTEM

In the study of reaction, it is first of all necessary to point out that there must be certain mechanisms to react. These have been called *effectors*. Quite obviously *muscle* is one of the kinds of effector or reacting mechanisms. The reaction of muscle has already been described in the chapter on kinesthetic sensation. The function of muscle is to contract. When a muscle is stimulated it shortens and becomes thicker. Such a shortening, if the muscle is attached to bones or other movable parts, at one end, and a non-movable part, at the other, occasions a movement of the movable part to which it is attached. Muscles are of two types. The first of these is the *striped muscles* which consist of all of the so called *skeletal muscles*, one end of which, at least, is attached to one of the bones of the body. Some of the muscles of the internal organs, such as the muscles of the heart, are also striped muscles. The other kind of muscle, called *smooth* or *unstriped muscle*, is found only in some of the internal organs such as the intestines and other parts of the digestive tract and the walls of the arteries and blood vessels.

Another very important class of reaction mechanisms is the *glands*. Glands are sacs in which are stored or produced certain liquids known as *secretions*. The stimulation of a gland liberates a certain amount of its particular secretion. Glands are of two sorts. There are the *duct glands* which have a tube or duct from the gland to another part of the body. When a duct gland functions, the secretions flow from the gland outward through this tube. The salivary glands are examples of the duct type. In the case of the salivary glands there are small tubes leading from the gland to the mouth. When the salivary glands are stimulated the secretion, known as saliva, flows from the gland through these ducts into the mouth.

There are also the *ductless glands* which are not provided with a tube-like outlet. The *adrenal glands*, about which more will be said later, are examples of the ductless type. When a ductless gland is stimulated, the secretion is liberated, not through a duct, because this does not exist, but directly into the blood stream. This discharge of the secretion into the blood stream is possible, of course, because all ductless glands, like every other organ in the body, are supplied with blood. The secretion of the ductless gland, discharged into the blood stream, is then carried by the blood to some other part of the body.

Reaction mechanisms are thus seen to be of two types: muscles (smooth or striped) which contract when they react, and glands (duct or ductless) which expel a secretion when they react. But neither muscles nor glands react unless they are stimulated. It can be said at once, and it cannot be emphasized too strongly, that no reaction ever takes place spontaneously. The effectors react only when they are stimulated by nerve energy by nerves which supply them. There is nerve supply to both muscle and gland and the reaction of either occurs only if nerve energy reaches and stimulates them through the nerves.

But nerve energy does not start spontaneously in the nervous system. Nerve energy flows only when the nervous system is stimulated by some physical stimulus affecting it, or as it is called, impinging upon it. In the nervous system there are special structures whose particular function it is to receive physical energy. These are called *receptors* and all of the sense organs of the body fall into this group of nerve structures. As much as seems necessary about the structure of the different end organs or receptors has already been discussed in the preceding chapters on sensation. In some way, not as yet adequately explained by physiology, these end organs transform the physical energy of the stimulus into what has been called nerve energy.

It may be set down as an infallible rule, then, that there is never reaction without stimulation of an end organ. There is never reaction of an effector of any sort without stimulation of a receptor as a basis. The problem of reaction, then, is partly a consideration of how the energy of the stimulus impinging on a receptor may, as nerve energy, stimulate an effector and cause it to contract, if it is a muscle, or secrete, if it is a gland. Thus the consideration of reaction involves the study of the *reaction arcs,* each of which has a sense organ at one end, a reacting mechanism at the other and some sort of nerve connection between the two. It is the nervous system which supplies the necessary connection between receptor and effector. In order to understand reaction, therefore, it is necessary to know about this nervous system.

It may be said frankly that the rest of this chapter is not psychology. It consists of a brief description of certain important facts of the anatomy and physiology of the nervous system. But an understanding of reaction is not possible without a knowledge of these facts and principles. In this discussion of the nervous system, the emphasis will be upon broad principles rather than on detailed facts. The figures will be simplified schemas rather than attempts at the depicting of accurate detail. So far as possible, technical terms will be avoided. If the reader is interested in the technical anatomy of the nervous system, his attention is called to any one of the more technical references given at the end of this chapter.

The nervous system, like every other structure in the body, is composed of a collection of cells. The particular sort of cell of which the nervous system is composed is called the *neuron.* Every typical neuron has three parts as illustrated in figure 80. The central part (*B*) is the *cell body* which is fig-shaped. The cell body is so small that, in a properly stained specimen, it can just be seen without the aid of a microscope. From the pointed end of the cell body grows a long single threadlike process called the *axon* (*C*). The end of the axon which is away from the cell body usually breaks up into a number of branches as indicated in the figure above. The axons are what are commonly thought of as nerve fibers. Nerves, as they are popularly understood, are composed of bundles of these axons. The figure above misrepresents the relationships between the size of cell body and axon. The cell body, which is microscopically small, may have an axon at least three feet in length. Hence a cell body of the size of the one pictured above might have an axon more than a half a mile long, if it were drawn in the proper proportions. The reader has already been warned that the drawings of the nervous system are entirely schematic.

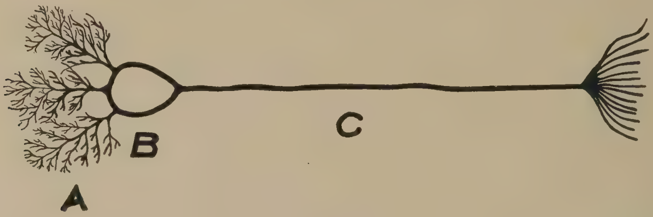

Fig. 80

From the flat end of the cell body, one finds a number of short, highly branched processes (*A*) known as *dendrites*. Each typical neuron is thus composed of a cell body, axon and dendrites.

It is found, on the fully developed neuron, that there is a deposit of a white glistening fatty substance known as *myelin*. This substance covers the axon like a sheath. Nerves appear white and this is because they are bundles of myelinated axons. The function of myelin on the axon is believed by some to be that of insulation of the particular nerve fiber from adjacent nerve fibers. Its function is the same as the insulating surface of an electric wire, namely, to keep the nerve energy within the confines of the particular neuron and thus to prevent it from flowing over to adjacent nerve fibers.

The presence and color of myelin on the axon gives the basis for the distinction between the so called grey matter and white matter of the nervous system. White matter has been found to consist of collections of myelinated nerve fibers or axons. Grey matter consists of groups of cell bodies and dendrites, none of which are ever myelinated.

In the embryological and individual development of the neuron, the first stage consists solely of the cell body. At first the cell body is present without axon or dendrites. The cell body at this stage is known as a *neuroblast.* The neuroblast develops into a neuron by the growth, from it, of the axon from the pointed side and the dendrites from the flat side. Myelin appears on the axon after it has reached practically its full development.

If an axon should be cut, providing the injury is not too close to the cell body, there is evidence that the severed part disintegrates but that the destroyed part of the axon may grow again. If a cell body is destroyed, however, all of the other parts of the neuron rapidly disintegrate and none of the parts are ever replaced. The destruction of a cell body means that the entire neuron is lost forever. Each individual is born with his full complement of nerve cell bodies, although many of these are in the neuroblast stage and have not developed into neurons at the time of birth. The history of the individual nervous system is that of the loss of neurons, by accident, disease or senile decay, from birth to death. How complicated the nervous system is, may be envisaged from a consideration of the estimate of a conservative authority, who indicates that there are 9,280 million (9,280,000,000) nerve cells on the surface of the brain alone. In the entire nervous system, the total number of nerve cells is considerably more than this number.

In the developed nervous system, these neurons are connected with one another in chain-like fashion as is indicated in figure 81. It will be remembered that an arrow is the symbol representing stimulation of the nervous system by some physical stimulus impinging upon it. Several general principles will become evident from a study of this figure. The part of the neuron which receives the physical stimulus is the group of dendrites. The nerve energy then passes through the cell body outward along the axon. Nerve energy never travels in the opposite direction along an axon toward its own cell body. It is not possible, therefore, to stimulate a cell body through its own axon. The end of the axon of the first neuron (1) is in close relation with the dendrites of the next neuron (2). There is evidence that a very small but actual gap exists between the axon of any neuron and the dendrites of the next neuron. Neurons are thus seen to be entirely independent cells which do not grow into one another. This gap between the axon of one neuron and the dendrites of the next is called the *synapse*. Hence, in this figure, it will be seen that the stimulation of the dendrites of neuron (1) will lead to nerve excitation passing outward from the cell body along the axon of this neuron. This nerve energy then crosses the synapse at *A* and stimulates the dendrites of neuron (2). Passing outward along the axon of this neuron, the nerve energy passes the synapse at *B* and stimulates the dendrites of neuron (3) and so on.

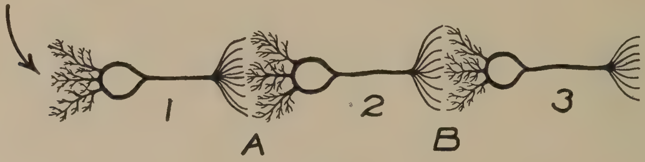

Fig. 81

There is another type of neuron called *atypical* or *bipolar* which differs from the typical neuron in only one important respect. Like the typical neuron the bipolar neuron, which is schematically illustrated in figure 82, has a cell body, a myelinated axon and dendrites. But in the typical neuron the dendrites grow directly out of the flat side of the cell body. In the bipolar or atypical neuron these dendrites are separated from the cell body and are connected with it by a long axon-like process indicated by the *A* in the figure. The bipolar neurons are the kind that are characteristic of the nerve cells found in the sense organs. They are therefore the characteristic receptor neurons.

On the basis of this knowledge, we can thus correct and enlarge the schematic representation of the chain of neurons, illustrated above, by substituting a bipolar neuron for neuron 1 and by having the end of the axon of neuron 3 stimulate some reactive mechanism, such as a muscle. With these changes the chain of neurons would appear as in figure 83.

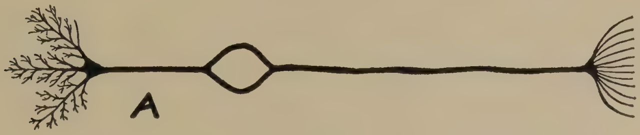

Fig. 82

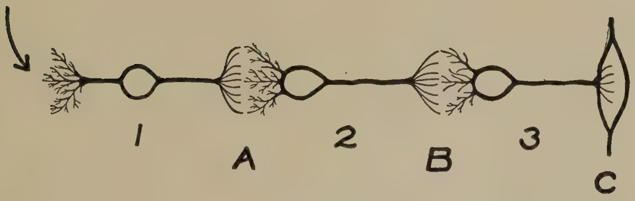

Fig. 83

This figure represents all of the essential neural elements of a reactive arc. Neuron 1, which is of the bipolar form, has the dendrites removed from the cell body and these are located in a sense organ. This is the receptor. The typical neuron 3 has its axon ending in a reactive mechanism, in this case a muscle. This is then an effector. Typical neuron 2 connects the axon of neuron 1 with the dendrites of neuron 3. The atypical neuron 1, at the one end of the arc, is called a *sensory neuron* because it is a receptor. The typical neuron 3 is called a *motor neuron* because it is connected with an effector. The typical neuron 2 is called a *connecting* or *communicating neuron* because it completes the reactive arc between receptor and effector.

Hence the stimulus, indicated by the arrow, impinges on the dendrites of the receptor. The nerve energy aroused by the stimulus passes across the first synapse (at *A*), along the axon of the communicating neuron and across the second synapse (at *B*) to the effector neuron. The nerve energy then proceeds outward along this axon to the muscle which contracts.

The nature of this nerve energy is not completely understood. It has already been indicated that no one can adequately explain the nature of the transformation, in the sense organs, of the physical energy of the stimulus into the nerve energy which passes into the nervous system. Many different kinds of theoretical explanation exist for each of the different sense organs. It has been suggested that nerve energy may have its basis in the biological movement of the cell itself or that it may be in the nature of some chemical change in the composition of the cell substance. More recent evidence indicates that nerve energy is intimately associated with electrical energy. It has been found that there are electrical currents created in nerve tissue whenever there is nerve activity. These have been called *action currents.* With the development of recent apparatus, it is now possible to measure the strength and other characteristics of these action currents. It is also possible, in some cases, to substitute an electrical stimulus for normal nerve energy. To demonstrate this fact one cuts out the calf muscle from the leg of a frog and carefully dissects out the nerve fiber which supplies it. Then, if the nerve fiber, which is really a bundle of myelinated axons, is stimulated electrically, this will prove to be an adequate stimulus substitute for normal nerve energy, and the muscle will contract.

The human nervous system is divided into three parts. These are the *peripheral*, the *central* and the *sympathetic* parts of the nervous system. Each of these parts will be described as clearly as the available space allows and with an avoidance of technical terms wherever possible. Practically all of the structures in the nervous system are duplicated on both sides of the body so as to make the nervous system bilaterally symmetrical.

The *peripheral nervous system* consists of what we popularly think of as nerves. On the one hand, there are the so called *sensory* or *afferent* nerves which consist of the axon-like connections of the dendrites of the receptor neurons to their cell bodies. On the other hand, it consists of the *motor* or *efferent* nerves, which are the axons connecting the cell bodies of effector neurons to a reaction mechanism. Afferent fibers carry nerve energy from the end organs to the central nervous system. Efferent fibers carry nerve energy from the central nervous system to reaction mechanisms.

The peripheral nervous system consists of 31 pairs of nerves which enter or come out from the spinal cord and also 12 pairs of nerves which are directly connected with the brain. Some of these nerves, like the optic nerve from the eye to the brain, are made up entirely of afferent fibers and are called *sensory nerves*. Others are composed entirely of efferent fibers and are called *motor nerves*. But most of the nerves making up the peripheral nervous system are composed of both afferent and efferent fibers and are called *mixed nerves*. All of the pairs of spinal nerves are of this mixed type. In the schematic figure above of the reaction arc, the two external ends of neurons 1 and 3 would be found in the peripheral nervous system.

The rest of this figure consists of parts of neurons which would be found in the *central nervous system*. The central nervous system consists of two parts—the *brain* and the *spinal cord*. The brain may be conceived as an enlargement of the upper end of the spinal cord. A schematic picture of the brain and spinal cord is given in figure 84. This shows the underneath side of the brain and the front of the spinal cord in order to indicate how the fibers of the nerves of the peripheral nervous system enter or leave these two parts of the central nervous system.

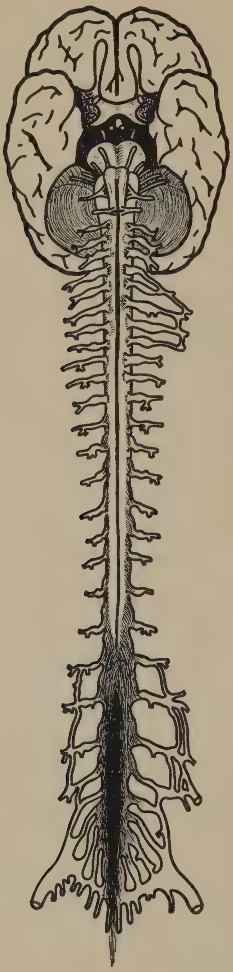

Fig. 84

White and gray matter, myelinated axons and cell bodies, which are, respectively, both found in brain and spinal cord. In the spinal cord the cell bodies (gray matter) are largely located in the central portions surrounded by or imbedded in masses of white matter (myelinated axons). In the brain, the surface, called the *cortex,* is a mass of layers of cell bodies (gray matter) and the structures in the inside of the brain are largely white matter with certain masses of gray cell bodies as well. A more detailed description of some of the connections in the spinal cord will be given in the two succeeding chapters.

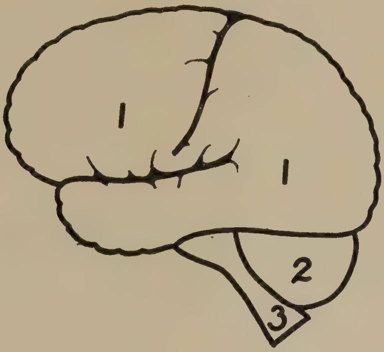

Fig. 85

The brain may be considered as the coördinating organ of the nervous system. The spinal cord may be considered as the distributing organ inasmuch as the spinal cord contains nerve tracts running from sense organ to brain and other nerve tracts from brain to reacting mechanism.

The brain may be divided into three main parts. Figure 85 indicates their relative size and location. The major part (1) is that called the *cerebrum* and it is this part which is popularly thought of as the brain proper. It comprises nearly four-fifths of the nerve structures within the skull. Below and behind the cerebrum is another large structure (2) which is called the *cerebellum.* The third brain structure (3) is the *brain stem* or *medulla oblongata.* It can be seen that this is really a continuation of the spinal cord connecting it with the cerebrum and cerebellum.

The surface of the brain is not smooth but is deeply indented with what have been called *fissures.* Figure 86 is a view looking down on the top of the brain. The cerebrum, cerebellum and medulla oblongata are numbered respectively 1, 2, and 3 as they were before. It will be seen that there is one very deep fissure running from front to back which almost separates the cerebrum and cerebellum into two halves. These halves have been called the right and left *hemispheres* of the cerebrum and cerebellum respectively. The terms right and left are applied with regard to the normal position of the brain in the body.

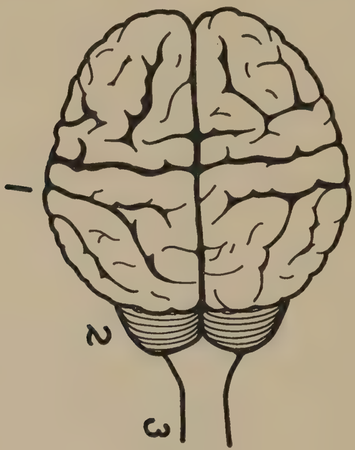

FIG. 86

Figure 87 is a schematic drawing of the surface of the brain looked at from the side. This would show the left hemisphere. Only the very important fissures are shown. There are many more fissures than are shown in this figure in any actual adult human brain specimen which one might examine. The raised space of brain surface, between two fissures, is called a *convolu-*

tion. Two of the fissures (marked *A* and *B*) are larger and deeper than the others. The vertical fissure (*A*) is called the *Fissure of Rolando* and the horizontal fissure (*B*) is called the *Fissure of Sylvius.* The fissures and convolutions will be found to be similar in both hemispheres of the cerebrum.

These two fissures and some others are taken as dividing each hemisphere of the cerebrum into four parts which are called *lobes.* The lobes take their names from the bones of the skull under which they lie. In the front part of the brain are the *frontal lobes* (1). In the back part of the brain are the *occipital lobes* (4). In the lower part of the cerebrum are the *temporal lobes* (3). The *parietal lobes* (2) are found in the upper central parts of the cerebrum.

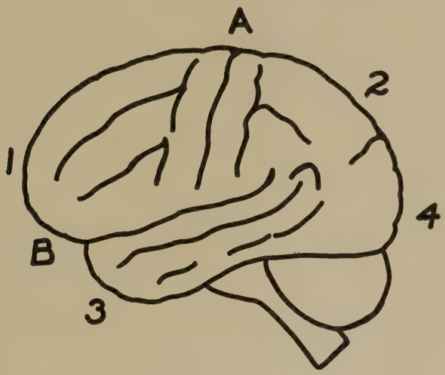

FIG. 87

On the inside surface of the great fissure which runs longitudinally almost cutting the two hemispheres in half, there are also fissures and convolutions. Figure 88 shows the important convolutions and fissures on these internal surfaces facing each other on opposite sides of this great fissure. All of the shaded portion in the lower part of the figure represents certain internal structures beneath the brain surface.

One general principle with regard to the function of the brain cannot be overemphasized. *There is never consciousness without* *nerve energy reaching and stimulating certain parts of the surface or cortex of the cerebrum.* Not all of the corthical surface, owever, is concerned with matters of consciousness.

From a great many sources there is evidence that certain parts of the cortex are particularly responsible for different kinds of conscious and motor function. The facts of *cerebral localization* have been derived by many methods and their correctness checked by other methods. In cases of brain tumor of skull fracture, surgeons are able to study the symptoms of the patient and, from a knowledge of cortical localization, know just where to open the skull in order to expose the exact part of the brain affected. Experiments to determine the localization of functions of the different parts of the cortex have been made with animals by opening up the skulls and thus exposing limited areas of the brain surface. These limited areas are then removed by cutting out or washing away the nerve cells of the cortex and then studying the changed behavior of the animal after it has recovered from the operation. Sometimes nature performs this experiment for us in humans in the reverse order. Sometimes, because of accident or disease, there will be the destruction of brain tissue in a limited cortical area. The symptoms of such an individual are studied and then a post-mortem examination of the brain will reveal the parts of the brain surface in which the cell bodies have been destroyed.

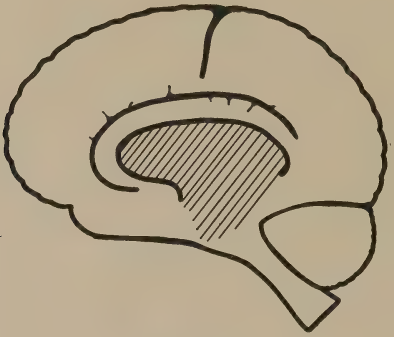

Fig. 88

In both animals and humans when an operation on the brain is necessary, it has been found possible and useful to stimulate the brain surface with a mild electric current and thus determine which portions of the cortex are motor in function. If the motor areas of the brain are so stimulated, there will be a contraction of certain muscles while the electrical stimulation of other parts of the brain surface will not give any reaction at all.

Finally, examination through a microscope of stained brain tissue reveals that there are differences in the kind of cells and in the arrangement of the cell bodies of which different parts of the cortex are composed. A study of these differences is of assistance in delimiting the extent of each of the cortical areas which differ in function. The results of these many observations by the several different methods are summarized in the two figures below. It will be recognized that the first of these figures is a schematic representation of the outer surface of a left hemisphere (fig. 89) while the second is a representation of the inner surface of a right hemisphere (fig. 90).

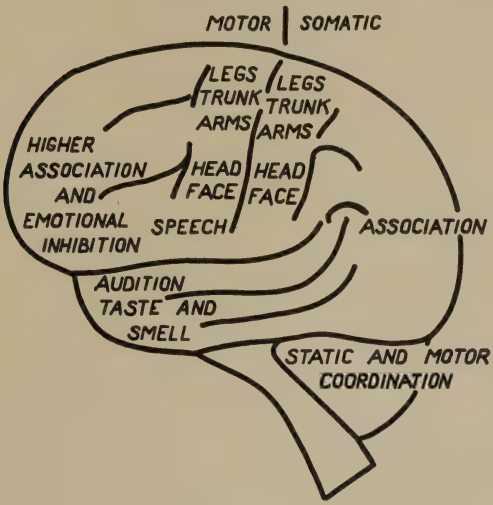

Fig. 89

The convolution directly in front of the Fissure of Rolando is entirely motor in function. Electrical stimulation of any part of this surface will result in the contraction of some muscle of the body. The left side of the brain controls the muscles of the right side of the body and vice versa. There is an abnormal condition, known as *hemiplegia* which consists of paralysis of the muscles on one side of the body. If the muscles of the right side of the body are paralyzed, one may know that there has been a destruction of the cells of the *Pre-Rolandic Convolution* on the left side of the brain. There is a complete crossing over or *decussation,* as it is called, of the fibers from the cell bodies in the motor area on one side of the brain to the muscles in the opposite side of the body.

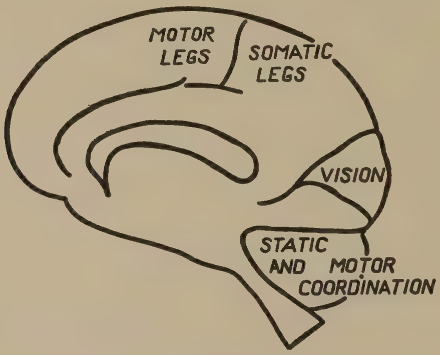

FIG. 90

There is also a complete reversal of the vertical relations as well within each motor area in either hemisphere. The upper part of the Pre-Rolandic convolution controls movements of the legs. Movements of the trunk and arms are controlled by cells located in the middle part of this area. And the lower part of the motor area controls movements of the muscles of the neck, head and face. Hence destruction of the upper third of the right Pre-Rolandic convolution would result in paralysis of the muscles of the left leg. Some of the leg area will be found to extend over into the inner surface of the cerebral hemispheres.

The cortex of both hemispheres of the cerebellum is also concerned with certain motor functions. These parts of the cerebellum supply the exactness of coördinations to gross movements. The destruction of large parts of the cortex of the cerebellum is always accompanied by a loss of muscular coördination. A patient with such a loss could not make the finely coördinated movements of fingers or even the grosser movements of the arms or legs in walking with any great degree of exactness. The cortex of the cerebellum is also partly sensory in function and, in this respect, is primarily concerned with the static sensation arising from stimulation of the semicircular canals and with the muscular adjustments following these sensory cues necessary to maintain the body in an upright position. The instability of alcoholic intoxication is partly, at least, due to effects upon the cortex of the cerebellum.

There is still one other cortical area primarily concerned with motor function. In the lower part of the cerebrum, just in front of the area for motor functions of the muscles of the head and face, is an area marked *motor speech.* This is known as *Broca's Area* in honor of its discoverer and historically it was the first area to which was assigned a definite localization of function on the brain surface. It is the area concerned with the very delicate muscular movements involved in articulate speech. If this area of the cortex should be destroyed, but with all of the rest of the brain surface intact, the patient would be unable to speak. He would have a complete motor aphasia. This would be true in spite of the fact that he would be able to use and there would be no evidence of paralysis of the individual muscles utilized in articulation. But the close relation of this area and of the motor area for the muscles of articulation is evident.

Broca's Area is found only in one hemisphere of the brain and it is the only cortical area which is not duplicated in both hemispheres. It is found always on the side of the brain opposite the more usable hand. Thus Broca's Area for articulate speech is found in the right hemisphere in left handed people and in the left cerebral hemisphere in right handed people. And it is found that every individual is either right or left handed. If the tests of handedness are made difficult enough it has been found that the coördinations of one hand break down before those of the other. No one is absolutely ambidextrous. The function of the corresponding area in the other hemisphere has not been definitely determined.

There are four main sensory areas on the cortex of the cerebrum. The convolutions just in back of the Fissure of Rolando (called the *Post-Rolandic Convolution*) are marked *Somatic* in the figures of both the external and internal surfaces. These are the sensory centers for the kinesthetic sensations; for all five modalities of cutaneous sensation; and for organic sensations. Although these seven modalities give different kinds of sensation and although each has its own special end organs, the afferent fibers from all of them eventually collect in a common single center. Again, as in the motor centers, there is a complete reversal of both vertical and horizontal relations between brain center and parts of the body. The fibers of sense organs on the right side of the body reach the left brain area and vice versa. And the upper third of this area receives impressions of stimulation of the legs; the middle third from the trunk and arms and the lower third from the neck, head and face.

The sensory center for vision is found on the inner surfaces of the occipital lobes in the back part of the brain in the great fissure between the two hemispheres. Only half of the fibers from each eye decussate to the opposite side of the brain. Complete destruction of both of these areas would result in total blindness even though the eyes themselves should remain entirely uninjured.

The cortical centers for audition are found in the upper part of the temporal lobes in the lower central part of the brain. Destruction of both of these areas would result in total deafness although the auditory mechanisms of the ears might remain completely intact. In the lower tip of the temporal lobes are found single sensory areas for taste and smell. The fact that these two sensory modalities, each with a different end organ, are so closely associated in regard to cortical area may be the reason for the confusion of these kinds of sensation in common experience.

There are then four primary sensory areas in each cerebral hemisphere: (1) vision; (2) audition; (3) taste and smell and (4) general somatic including all of the kinesthetic, cutaneous and organic modalities of sensation. In the charts it will be observed that each of these primary sensory areas is surrounded by a shaded area, in each case with the shaded lines converging upon the central primary area. These shaded areas have been called the *secondary sensory areas.* There is very good evidence that the modification of brain tissue, which is the basis for the image, occurs in these secondary areas. The function of these secondary areas seem to be as specific as the particular primary sensory areas which each surrounds. The shaded portion about the primary auditory area is the part of the brain surface responsible for the auditory image. The shaded parts surrounding the primary visual area, including most of the occipital lobe on the external brain surface, are responsible for visual images, and so on.

The evidence for this specificity of function of these secondary areas rests upon experimental evidence such as the following. A dog was trained to give appropriate reactions to two different auditory stimuli. After this learning was completed, his skull was opened and the secondary auditory areas were removed leaving the primary auditory areas intact. When the animal recovered from the operation, it was found that he could still hear. This was evidenced by his ears standing up to any auditory stimulation or by his turning his head toward a source of sound. But although he could hear, he had totally lost his differential reactions to the special auditory stimuli. These were no longer meaningful to him. The destruction of these secondary auditory areas eliminated his auditory apperceptive background by destroying the modified brain tissue which could be the basis for auditory images. Hence auditory perceptions were impossible without the contribution of apperception, although sensation was still possible because the primary area remained intact.

On the chart of the external surface of the brain, an area will be noticed in the upper part of the parietal lobe marked "*Association.*" It will be observed that this area has an almost central position among the four secondary sensory areas which surround it. There is evidence that the destruction of this area of the brain results in an elimination of the ability to recall ideas across two sensory modalities. Hence, if this area alone is destroyed, the subject could obtain with adequate stimulation a proper perception of the tone of a violin but he could then be unable to call up a visual image of what the instrument looked like. This later visual image is impossible because it involves an association between the auditory and visual areas which must pass through this association area. Similarly, if this individual had a visual perception of the violin he would be unable to call up an auditory image of the sound of the instrument.

Referring back to the charts of the brain surfaces, the reader will find that there has now been discussed all of the central and back surfaces of the cortex and that various special functions have been assigned to various areas. There still remains the very large area in the frontal lobe including everything in front of the motor area except Broca's area for articulate speech. It will be seen that this is a large area comprising probably more than one-fifth of the entire brain surface.

In spite of the magnitude of this so called *pre-frontal* area little is known regarding the function which may be assigned to it. It has been found that large parts of this area may be destroyed without apparently any loss of either special sensory or motor functions. One of the important cases recorded is that of a young man who was tamping a blast of dynamite when it exploded prematurely. The crowbar, acting as a projectile, went through the chin, completely through this pre-frontal area and out the top of his head. The man recovered and there seemed to be no loss of sensory or motor function nor any lowering of general intelligence. The only abnormal symptoms which he exhibited were great irritability, a certain degree of loss of emotional control and an inability to plan and carry through any particular program. These symptoms were so mild that they might have been solely the result of the general nervous shock occasioned by an accident of this degree of gravity.

But a statistical study of the symptoms of many cases of destruction of this pre-frontal area indicates, almost invariably, this same loss of emotional stability, of planfulness and increased nervous irritability. It seems safe to say, in the present state of our knowledge, that this pre-frontal area is the center for some of the more complex associations and for emotional control and emotional inhibition. Some very recent results of experimental destruction of this area in chimpanzees and monkeys also indicate that these operated animals are unable to retain memories of very recent perceptual experiences. Such a loss of recent memories could very well be the basis of the lack of planfulness exhibited by many cases in which large parts of this area were destroyed.

There are some experimental results of destruction of cortical cells which some investigator has used to argue against the concept of strict localization of function in specific cortical areas. This investigator has developed a remarkable surgical and experimental technique and he has used many hundreds of animals in his experiments. The animal which he employed was the rat. With certain very few exceptions, he finds that he may destroy any part of the brain surface of a rat without loss of what this animal has learned, or if such loss occurs, he finds that the animal is able to relearn readily what it has lost. He correlates loss of function with the extent of brain area destroyed rather than with the position of this destruction on the brain surface, with some few exceptions.

In discussing these results, another authority is perfectly willing to accept their accuracy as applied to the rat, but doubts their applicability to the human central nervous system. He points out that the central nervous system of the rat is very much less complex than the nervous system of man and he doubts, for this reason, if these results obtained from rats will apply to cortical localization in man.

It is the author's belief that the cortical localization of function in man has been well established. Brain surgeons continue to know where to open the skull on the basis of symptoms exhibited by the patient. But it must certainly be admitted that the exact extent of these various localized areas cannot be so sharply defined as it was once believed. Certainly there is much overlapping of different areas at their boundaries, but this overlapping is somewhat diminished because many of the boundaries are well defined by deep fissures.

The inside of the brain is primarily constructed of pathways of association between the different centers of the brain and of pathways from the brain to the effectors and receptors of the body. The latter have been called *projection fibers*. These projection pathways are all composed of white matter (myelinated axons) and they are all subcortical, that is, lying under the layers of cell bodies which form the brain surface.

There are four main groups of such pathways. (1) The first of these projection pathways carries nerve energy up the spinal cord from the receptors to the brain and down the spinal cord from the brain to the effectors. In figure 91 tract *A* schematically represents the *sensory tract* which carries nerve energy from the sense organs upward through the spinal cord, through the medulla oblongata or brain stem, through certain structures inside the brain and finally, through many branches, distributes this nerve energy to the appropriate centers on the brain surface. The *motor tract,* marked *B* in this figure, collects through its many branches the nerve energy of stimulation of the motor area of the cortex. These branches collect into tracts which pass through the medulla oblongata and then downward through the spinal cord to branch out eventually to the effectors. In this chart, these two tracts have been represented as continuous. This is an inaccurate simplification of the facts. Actually between cortex and medulla in the tracts running in either direction the nerve energy passes through several relay stations, each involving new neurons rather than a single continuous axon as has been indicated.

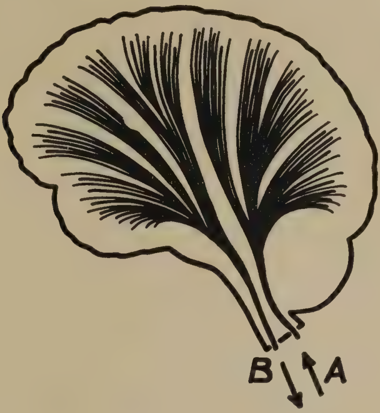

FIG. 91

Figure 92 represents the third kind of projection pathway whose function is to carry nerve energy from one hemisphere of the cerebrum to the other. This chart represents a vertical transverse section of the brain cut transversely. Above and in the center will be observed (*A*) the great fissure which runs longitudinally from front to back and divides the cerebrum into two hemispheres. At the bottom of this great fissure and forming the roof of the internal structures of the brain has been indicated (*B*) the heavy band of white matter dividing at both ends to distribute the nerve energy from one hemisphere to the cortex of the opposite hemisphere.

The fourth main type of projection fiber is illustrated in figure 93. This is a schematic representation of a vertical longitudinal section of the brain. It is as if one cut down through the bottom of the great fissure and entirely separated the two hemispheres of the cerebrum. The structure marked *A* represents a cross section of the heavy band of projection fibers crossing from one hemisphere to the other discussed in the paragraph above.

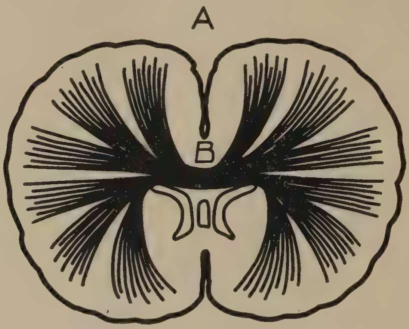

FIG. 92

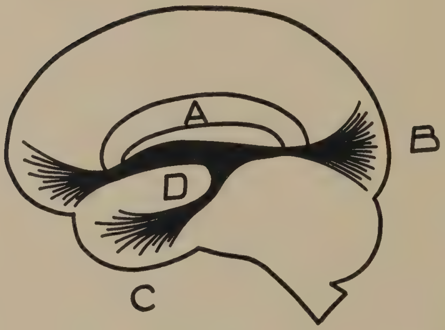

FIG. 93

The rest of this figure represents a projection which afford connections between the cortex of the temporal, occipital and frontal lobes in either hemisphere. It is marked *E* (Frontal lobe end); *B* (Occipital lobe end); *C* (Temporal lobe end) and *D* (Main pathway). It will be observed that all of the three ends of this tract have many branches for distributing nerve energy very widely to different parts of the cortex and to many different cortical areas.

The concept of looking at the brain as a sort of telephone system is no longer in fashion. However, it still seems a useful explanatory device for the understanding of relationships within the central nervous system. One may conceive of the various cortical centers each as a telephone exchange in a large city. Naturally there are telephone lines connecting the different instruments within a given exchange. For the sake of simplicity these have not been represented in the charts. Each exchange (or cortical center) has lines of connection with every other center. These are represented in the last two charts as the projection pathways from one hemisphere to the other and as the projection pathways connecting the frontal, occipital and temporal lobes. Besides there are lines of fibers connecting the appropriate exchanges for suburban calls. These are represented in the third chart above as the projection pathways up the spinal cord to the cortex of the brain or down the spinal cord from the cortex. We shall find, in the succeeding chapters that there are also direct connections between the receptors and effectors at the lower spinal levels. Thus stimulation of a receptor may result in stimulation of an effector over the direct line without going to the brain at all.

The discussion of the functions of the parts of the brain would be incomplete without mention of still another group of small but highly important structures. These are found on the top of the medulla oblongata. They control certain automatic functions of the body such as the heart beat and breathing. These important structures are masses of cell bodies which are located in the brain stem and not in the cortex.

The third great part of the nervous system is called the *sympathetic* or *autonomic nervous system.* This consists of a series of nerves which supply energy to many internal organs. These nerves lie in two tracts which run parallel to and just outside of the spinal cord. At the different levels there are nerve connections between the spinal cord tracts and those of the sympathetic nervous system. The sympathetic nervous system is responsible for the nervous control of many automatic functions of the internal organs.

Automatic functions dependent upon nerve supply which are served through the sympathetic system are those of the arteries and blood vessels, the digestive tract, the lungs, liver, pancreas, salivary glands, spleen, generative organs, bladder and kidneys and others. The importance of this part of the nervous system in human physiology is obvious therefore. In many cases, such as the action of the lungs, a dual control is possible. The normal automatic functions are supplied by nerve energy through the sympathetic nervous system, while volitional control may at times be possible through the central nervous system by way of the connections between the central and sympathetic nervous systems.

In the study of the nervous system we have found that the neuron is the structural unit because the nervous system is composed of neurons in the same way that a house is composed of bricks. But the functional unit of the nervous system is the reaction arc. This consists of at least three neurons with two synaptic connections. At one end of the reactive arc is a sensory neuron, the dendrites of which are embedded within an end organ. At the other end of the reactive arc is a motor neuron, the axon of which is in connection with an effector—either a muscle or gland. Between the sensory and motor neurons is a connecting or communicating neuron, which forms synaptic connections with both sensory and motor neurons and therefore may be considered as a *point of transfer* between the sensory and motor ends of the reactive arc.

In the succeeding chapters much more will be said about the nature and anatomical localization of these connecting neurons as the basis of the differentiation of the psychologically different forms of reaction. It will be found that reflex, instinct, volition and habit are each differentiated from the others physiologically by the anatomical position of the point of transfer between the sensory and motor ends of the reactive arc. These differences in localization of the points of transfer for the different kinds of reaction will be found useful in helping to explain the psychological differences between reactions of the different types.

QUESTIONS

1. What is the importance of the stimulus in reaction?
2. Describe the typical and atypical neurons.
3. What is a synapse?
4. What is the best available explanation for the nature of the nervous impulse?
5. What are the major divisions of the nervous system?
6. What are the major divisions of the brain?
7. How are various functions localized in various parts of the cortical surface?
8. What is the function of the cerebellum?
9. What is the difference between primary and secondary areas of localization?
10. In what ways are the various structures within the brain and on its surface related with each other?

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Chapter XV

REFLEX

The simplest kind of reaction found in man has been called the *reflex.* It is possible to demonstrate a reflex reaction for oneself quite easily. Provide yourself with a mirror. Place your hand over your closed eyes for several minutes. During this dark period the pupils of your eyes will have become dilated. Then uncover your eyes and observe in the mirror what occurs to the size of the pupils. When light strikes the eye you will find that the pupils contract in the presence of this increased light stimulus. This is a purely reflex activity known as the *pupillary reflex.*

A number of facts may be indicated about this reaction. In the first place, the reaction is never under voluntary control. It is never possible, under conditions of constant illumination and constant fixation, to change the size of the pupil when you wish. This change is accomplished only when the proper stimulus, which is a change in the intensity of the illumination, impinges on the sensory end of the reaction arc, thus leading to reaction of the effector at the other end of this arc. There is no consciousness or voluntary control of this particular type of reflex action. Not only is there no consciousness between stimulation and reaction, but in the case of the pupillary reflex, that consciousness never even follows the reaction. Practically one is never aware that the pupil is reacting in this reflex fashion. Indeed it usually occurs that most students have never been aware of this reflex action of the pupil until they have tried the experiment described above and that they are never consciously aware of the reaction even though they know it must be taking place.

Another demonstration of reflex reaction may be had by eliciting the *patellar reflex* or the so called knee-jerk. To obtain this, the subject should either sit on a table or cross his legs in such a fashion that one leg hangs entirely free and relaxed. You will be able to feel an indentation just below the knee cap. Closer examination of this indentation will indicate that you can feel the patellar tendon which may be pressed into this slight indentation. Having discovered this proper place, strike the tendon there with a sharp blow using the side of your hand. If the right place on the patellar tendon is stimulated, you will find that the lower leg will kick sharply outward. This reaction is the patellar reflex. We shall refer to this particular reflex reaction frequently in the discussions in the rest of this chapter because it is readily accessible for various kinds of demonstration.

There are many kinds of reflex activity in man besides the two already indicated. The normal activity of the changing of the lines of sight of the eyes for near and far vision and the changing of the curvature of the lens of the eye are both reflexes. The action of the stomach and intestines in digestion and the action of the glands which control the flow of saliva have a purely reflex basis. Such activities as yawning, sneezing, cramp movements and blushing are based upon reflex activity.

Some of these are reflex activities in their normal automatic occurrence although at times they may be under voluntary control. The eye-wink is an example of this sort of activity which normally is a reflex but may be under voluntary control. It is possible consciously and voluntarily to close the eye lids but normally this happens in purely reflex fashion as frequently as more than once a minute on the average, without one's being aware of the reaction at all.

Most of these reflex activities are highly useful in maintaining an efficient human organism. From this point of view, they may be considered highly *purposeful.* Obviously the reflexes involved in normal digestion indicate this purposeful aspect in the maintenance of normal human life and activity.

The purpose of the eye-wink reflex is to clean away the dust which may collect on the eyeball. Recent slow motion photographic studies indicate that this reflex is very complicated indeed but that it is most efficient for accomplishing its purpose. The edges of the eye lids fit closely over the eyeball, and therefore, act as scrapers as they move over this structure. The upper lid reacts downwards and the lower lid upwards, thus scraping the dust on the eyeball into a single line where the two lids meet. But if the two lids met exactly half way, the line of dust would be left across the pupil and would be in the way of the line of sight. This would interfere with the clearness of vision. To obviate this defect in the mechanism, the upper lid comes down farther than the lower lid comes up and hence the line of dust is collected somewhat below the line of sight. But if the action of the two lids was directly upward and downward, the dust scraped into a line would continue to collect and the deposit of dust would become larger and larger. This possible defect is obviated by a wave like motion in the closure of the two lids. They start to contract first at the temple side and the closure continues as a wave toward the nasal side of the eye ball. This form of movement not only collects the dust on the eye ball into a line but tends also to push the collected dust toward the corner of the eye on the side toward the nose. Hence, this reflex reaction of the eye-lid wink is exceedingly complicated and it is of a form most highly suited to perform adequately the function which it contributes to human well-being.

It has already been pointed out that there need be no consciousness involved in reflex, neither a directive consciousness nor even a consciousness that the reaction is taking place or that it has taken place. But reflexes do not start spontaneously. They always need a *stimulus* to set them going. For the knee-jerk the stimulus is the tap on the end organs in the patellar tendon. For the eye-wink reflex, it is the cutaneous stimulation of dust on the eyeball. For the salivary reflex it is the presence of food in the mouth and so on for other reactions. Each reflex has its particular normal kind of stimulation of a particular set of end organs which exist at the sensory end of the reaction arc.

The reflex action is *inevitable.* Given a proper adequate stimulation of a properly functioning reflex arc and the reaction will occur every time. In other words, if the stimulation situation remains unchanged, it is not possible to inhibit the reflex reaction. Try this with the patellar reflex. Be sure that you let the leg hang loose and relaxed as before but this time try to keep the leg from kicking. You will find that your leg will kick invariably upon proper stimulation provided that it hangs relaxed at that time. The only way that one may inhibit the patellar reflex at all is to prepare the leg before stimulation by contracting antagonistic muscles to such an extent that you may overcome the subsequent contraction of the muscles which normally react. But this is obviously changing the conditions for the normal reflex. Even in this case, if the reaction is a vigorous one, it will be found that the previous contraction of antagonistic muscles merely lessens the extent of the reflex kick and does not completely inhibit or eliminate it.

It has been found that the reflex reaction is curiously resistant to *fatigue.* If the lower leg should be exercised to the point that it can no longer be lifted voluntarily and then the patellar tendon is stimulated, it is found that the legs will react reflexly in a perfectly normal fashion. The limits of voluntary fatigue are therefore lower than those for reflex fatigue.

Also it has been found that the reaction time for reflex is considerably shorter than that of a voluntary reaction of the same bodily part. The latent time for the knee jerk between stimulation and the beginning of the response is less than $\frac{1}{50}$ of a second. Contrasted with this, it has been found that the latent time between stimulation and response for a voluntary kick of the leg is almost ten times as long.

How are reflexes to be explained? The best explanation is by appeal to the anatomy of the nervous system by indicating the localization of the various neural elements in the reflex arc. There are two kinds of reflex arcs in the nervous system. The *spinal reflexes* have their points of transfer between the sensory and motor ends of the reaction arc in the spinal cord, while the *cerebral reflexes* have their points of transfer in some of the internal, subcortical structures of the brain. The patellar reflex is an example of the spinal reflex and the pupillary reflex of the cerebral type. The anatomical description which follows will consider only the basis for spinal reflexes because the anatomy of these is simpler than those of the cerebral type and because both the spinal and cerebral reflex are based upon exactly comparable fundamental anatomy.

One cannot better introduce this topic than by the description of an experiment with a frog. It is not possible to destroy the brain of any warm blooded animal without causing death, because it will be remembered, the automatic centers for heart beat and breathing are located in the brain stem. But in cold blooded animals, like the frog, the centers for these automatic vital functions are not located in the brain at all, but are found much lower in the nervous system. Hence, it is possible to destroy the brain of a frog and keep the animal alive for a considerable period with proper care.

The chart (fig. 94) following illustrates four stages of this experiment. In the first stage, we have a normal frog with both brain and spinal cord intact. Such a frog will move away from a visual stimulus. It will jump away, that is, it will give a general reaction, if the toe of one foot is stimulated with a mild electric current.

In stage 2, the brain of this same frog has been destroyed but the spinal cord has been left intact. Such a frog will be found to have lost all ability to move in what may be considered voluntary fashion. It may be held up by its head, and in this position, its legs and body will hang down entirely inert. There is an almost total absence of any general bodily reaction such as jumping away to avoid a stimulus.

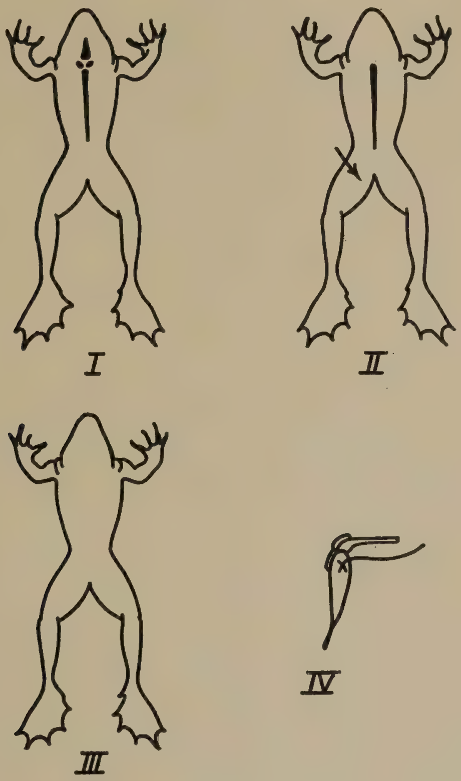

Fig. 94

This second stage, however, is the interesting stage of the experiment. It is found that a frog, with the brain destroyed but the spinal cord intact, will withdraw its foot if the foot is stimulated by a mild electric current or if the toe of the foot is pinched. If a small piece of blotting paper soaked in dilute acid is placed at the top of the leg, as indicated by the arrow in the figure representing stage 2, this leg will be raised in a thoroughly coördinated fashion until the stimulus is removed. More than this, if the acid stimulus be placed above the right leg and this leg is held so that it cannot be raised, it will be found that, after several unsuccessful reaction attempts of the right or stimulated leg, the left leg will then be brought up and the stimulus knocked away. This second stage of the spinal frog with the brain destroyed, illustrates true reflex activity.

The third stage of the experiment is accomplished by now destroying the spinal cord of the frog as well as the brain. Repetition of the same stimulation of the frog in this mutilated condition with brain and spinal cord both destroyed fails to lead to any reaction at all. One may apply electrical stimulation to the toe; one may pinch the toe or stimulate the leg with dilute acid, and the mutilated frog now hangs completely inert and does not react at all.

In the fourth stage, it is possible to dissect out one of the muscles of the leg and the nerve fiber which supplies it. It is then found that direct stimulation of either the muscle or the nerve with a mild electric current or a pinch of the forceps or acid stimulation of the nerve leads to contraction of the muscle. By this fourth stage, one demonstrates that the muscle was as able to contract and that the nerve fiber was as able to conduct nerve energy to the muscle in the third stage (when no reaction was obtained) as it had been previously in the second stage of the experiment (when the spinal cord was still intact and the animal reacted in reflex fashion).

But with the destruction of the spinal cord one has eliminated the point of transfer between the sensory and motor ends of the reflex arc so that it is no longer possible to get nerve energy to the motor axon and hence to the muscle after stimulation of the sensory end. And this experiment indicates that the point of transfer for these spinal reflexes is localized in the spinal cord. And we have also found, by the results of stage 2, that the brain is not necessary for the eliciting of these spinal reflexes. The neural situation may be indicated by the schematic diagram shown in figure 95. The essentials of this figure have been given in the previous chapter. They represent the simple reactive arc consisting of a sensory neuron, a connecting neuron and a motor neuron with its reactive mechanism. To this has now been added the lines A and B which indicate the outside limits of the spinal cord. Everything between these two lines is found in the spinal cord and everything else is found outside of the spinal cord.

In stage 2, with the spinal cord intact, all of these nerve structures were present and thus it was possible to get nerve energy from the dendrites of the sensory neuron, if stimulated, to the reaction mechanism causing the muscle to contract. In stage 3, the destruction of the entire spinal cord eliminated the axon of the sensory neuron, all of the communicating neuron and the dendrites and cell body of the motor neuron. Hence there was this break in the reflex arc and it was not possible to get nerve energy from the extreme sensory end of the arc to the reacting mechanism. All that remains, when the spinal cord is destroyed, are the dendrites and cell body of the sensory neuron isolated at one end and the axon of the motor neuron isolated at the other end of the former reaction arc.

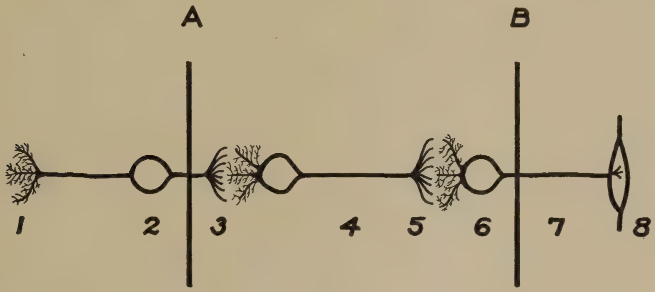

Fig. 95

It is worth while to see exactly where each of these various elements may be found within and outside of the spinal cord.

Figure 96 is a schematic cross section of the spinal cord and indicates these relations of localization. It will be observed the spinal cord is also divided into two hemispheres nearly cut through by two fissures. The inner butterfly shaped portion is composed of gray matter or a collection of cell bodies of neurons. These are surrounded by white myelinated axons which mostly run up or down the spinal cord. The front, or anterior part of the cord is in the upper part of the figure and the lower part is the back or posterior part of the spinal cord.

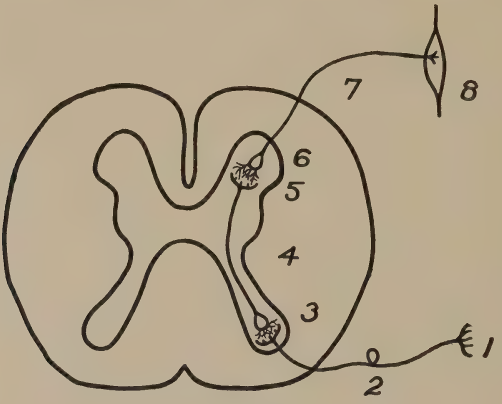

Fig. 96

If one will consider that the neural arc in the figure before this one was made of rubber so that one could pick it up off the page, then one could bend it and place it down on the section of the spinal cord of this figure. Thus each element would fall into its proper anatomical position as has been indicated. One will find that the numbers indicating the different parts of these three neurons correspond for these two figures.

Number 1 indicates the dendrites of the sensory neuron; while number 2 indicates the cell body of this sensory neuron which is located just outside and in back of the spinal cord in what is known as the *sensory nerve root*. The axon of the sensory neuron enters the posterior side of the spinal cord and forms a synaptic connection with the dendrites of the communicating neuron at number 3. Number 4 indicates this connecting neuron which lies entirely within the spinal cord and whose axon forms synaptic connection, at 5, with the dendrites of the motor neuron. The cell body of the motor neuron, at 6, lies in the gray matter in the anterior part of the spinal cord. The axon, marked 7, of the motor neuron breaks out of the spinal cord, in what is known as the *anterior nerve root* and goes to the muscle, at 8.

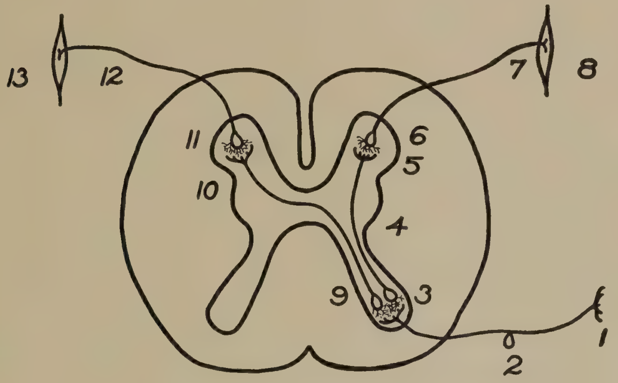

FIG. 97

Consider that the dendrites, at 1, are located in the toe of the frog and that the muscle, at 8, is in the leg of the frog. Then this neural mechanism explains the withdrawal of the foot of the frog by the contraction of muscle when the toe is stimulated only *provided that the spinal cord remains intact as in stage 2 of the experiment.*

This chart, then, explains all of the basic neural mechanisms for the reactions of the frog with the spinal cord intact but with the brain destroyed, except one. It does not explain the reflex contraction of the muscles in the *left* leg, to remove the acid stimulus, when the top of the right leg was stimulated but when the right leg was held and prevented from reacting. What happened in this case can be illustrated in figure 97.

As in the previous chart, the axon of the sensory neuron makes a synaptic connection with the communicating neuron of the same side, at 2, which would complete the reflex arc to the muscle on the same side of the body as that stimulated. But, inasmuch as this leg was held the contraction of this muscle was not possible. But the axon of the same sensory neuron is also in synaptic connection with another communicating neuron, at 9, whose axon (10) crosses to the opposite side of the spinal cord and is, in turn, in synaptic connection with the dendrites of a motor neuron (11) on the opposite side. The axon (12) of this motor neuron breaks out of the spinal cord in the anterior nerve root of the side opposite the sensory neuron and ends in a muscle (13) on this opposite side.

This figure explains all of the reflex activity described in the second stage of the experiment with the frog. If the spinal cord is intact, even though the brain is destroyed, the neural mechanism remains for reflex movements of muscles on either side of the body even if a sense organ on only one side is stimulated.

It cannot be too strongly emphasized, therefore, that an adequate neural explanation of reflex does not have to go beyond a *single level of the spinal cord*, in the case of the spinal reflex; or beyond a single level of sub-cortical structure in the brain in that of a cerebral reflex.

One can say, therefore, that reflex is an unlearned response. It has nothing to do with the past experiences of the individual. It is dependent upon the possession only of certain pathways in the nervous system. And there is evidence that these pathways are the result of normal growth of the nervous system and that the establishment of their synaptic connections is not based on individual past experiences. Experiments with the human foetus which has had to be taken from the mother, prematurely, indicate that the reaction of the patellar reflex and others are obtainable, and that the movements following such stimulation are accurate, at least three or four months before the time of normal birth. These reflex activities are dependent merely upon the existence of the appropriate reflex arc with its point of transfer in the spinal cord or lower brain centers. Given this complete and adequate reflex pathway in the nervous system and given an adequate stimulation of the sensory end of this reflex arc, one will always obtain the appropriate reaction. But the mere existence of the neural pathway is not sufficient to produce the reflex activity. It is also necessary to *stimulate* the sensory end with an appropriate stimulus. Such a pathway might exist indefinitely, ready to react if stimulated, but no reaction would ever occur unless the sensory end received the stimulation.

Until now we have spoken of the reflex arc as if it were a completely isolated mechanism in the nervous system. Nothing could be further from the truth. If one should go into the office of a neurologist for treatment of some nervous disorder, one of the first things which he would do would be to tap your patellar tendon and obtain your knee-jerk. He would closely observe the qualitative form of your reaction. He would determine if your patellar reflex was fast or slow; explosive or not explosive, small or of great extent. His observation would give him considerable information regarding your general nervous condition and even regarding certain aspects of your fundamental personality.

There is an old saying that "You can tell a lot about a dog from the way he wags his tail." This is really good psychology because the tail wagging of dogs has a reflex foundation. You can also tell a lot about a human from the character of his knee jerk reflex reaction. And there are wide individual differences in the speed, extent and explosiveness of the reaction in different men.

The author recently examined the reflexes of two very noted runners who had been competing against one another many times during the last several years. The first had a very slow, unexplosive patellar reflex of very small extent while the second gave a knee-jerk which was very fast, of great magnitude and highly explosive in character. The running of these two men exactly corresponds to their types of knee-jerk. The first man runs against a watch and maintains a constant speed throughout the running of a mile race. He never sprints at the end of the race if possible, and if he does, his sprint is only slightly faster than the pace he has maintained throughout the race. This man is not capable of the sudden explosive release of energy necessary for a final sprint in a race and his knee-jerk is of this same slow, unexplosive character. The other runner, with the explosive patellar reflex of great magnitude, runs his race in comparable fashion. He is capable of a sudden release of energy, and his race depends on a terrific final sprint to carry him to victory.

Thus there is evidence that the reflex arc, at the single level of the spinal cord, is not an isolated neural mechanism but that it is intimately connected with and forms a coördinated part of the entire nervous system. One can convince himself of this intimate connection of the single reflex arc with the rest of the nervous system by the following simple experiment. Have someone stimulate your patellar tendon and observe the extent of the reflex kick while you are perfectly relaxed. Repeat this several times until you are sure of the extent of your normal knee-jerk. Then clench your hands tightly and hold them tightly clenched just before another stimulation of the patellar tendon. You will observe in this case that you give a larger reflex kick than you did before when you were relaxed. The reflex is said to be *augmented* by the presence of other muscular activity at the time of stimulation. From this result, one can be sure that there is a connection between the normal reflex arc for the knee-jerk and the other parts of the spinal cord involved in clenching the hands.

Then try this experiment. This time sit perfectly relaxed and merely think of how it would feel to clench your hands. If while you are thinking in this way, someone taps your patellar tendon with the same intensity of stimulation as before, you will find that again there is a knee-jerk somewhat augmented or larger than the normal but probably not so much augmented as when the hands are actually clenched. This experiment demonstrates that even thinking may have an effect upon the extent of a reflex activity. But thinking has been seen to be a function of neural activity of the cortex of the brain. Hence this experiment indicates a relationship between the brain cortex and the reflex arc in the spinal cord.

It has been demonstrated that a reflex reaction has a particular form which cannot be imitated by a voluntary movement. It is not possible voluntarily to kick out your leg or wink your eyelids in a way which exactly imitates the form of the true reflex kick. The volitional reaction starts slowly and then increases in speed while the true reflex movement starts with a much greater initial speed than the volitional.

It has been demonstrated that there are regular and definite differences in the extent of the patellar reflex at different times of the day for the same individual. The knee-jerk will be of smaller extent at the end of a hard morning's work than it will be half an hour after an interval of rest and lunch. The curve of the extent of the reflex kick corresponds to the differences in the normal curve of voluntary work efficiency for the different times of the day.

One can conclude, then, given a reflex arc complete and in functional condition that one can predict a stimulation of the sensory neuron will result in a reflex reaction. The reaction occurs invariably and inevitably following stimulation. But one is not able to predict the *extent* of any reflex reaction because this is dependent upon the general condition of the nervous system in particular and of the organism as a whole and also upon what other activity, both motor and conscious, may be going on at the same time.

And now we must turn to another type of problem which has been of great interest to psychologists during the last three decades. Some 30 years ago an investigator was making a detailed and quantitative study of the knee-jerk. He was particularly interested in the question of the variability of the extent of the patellar reflex kick and the analysis of the conditions which were responsible for those variations. In order to study these problems, he had arranged an apparatus for taking graphic records of the movement of the leg. In order to keep the stimulation constant, he used hammers which fell through a constant known distance before they hit the patellar tendon. These hammers were held up by electro-magnets and were electrically released. One of his problems had to do with the effect of other muscular activity upon the extent of the reflex reaction. Hence, just before each stimulation of the hammers, a bell sounded which was the signal for the subject to clench his hands.

One day, after a long series of experiment with a particular subject, something went wrong with the apparatus. The signal bell rang, but the hammers did not fall. And, although unstimulated in the usual way by a blow on the patellar tendon, the subject gave a perfectly normal reflex type of kick. As the result of this accident there was the first experimental demonstration in man of what has been called the *conditioned* reflex.

The result of a patellar tendon reflex without stimulation of the sensory end of this particular reflex arc was so curious and so unexpected that this investigator turned his attention to the study of this phenomenon. He found that it was possible to substitute the bell stimulus for the actual tap on the patellar tendon in a number of subjects and so obtain the conditioned reflex reaction. In the study of this problem the usual stimulus (called the *normal stimulus*) of course elicits the *normal reflex*. The *secondary* or *conditioning stimulus*, in this case, the bell, becomes substituted for the normal stimulus to produce apparently the same reaction which is then called the *conditioned reflex*.

A number of facts have been found consistently by all investigators of the conditioned reflex. In the first place, it is necessary to stimulate the subject with the normal and conditioning stimulus almost simultaneously. What one does is to apply the normal stimulus in the presence of the conditioning stimulus. Thus, in the present case, the patellar tendon is tapped a short time after the bell has started to ring. It has been found that the conditioned reflex is hard to establish. In order to establish a conditioned knee-jerk to the bell stimulus, it has been found necessary to repeat the two stimulations simultaneously many times. Thus the conditioned reflex is seldom established in less than 200 stimulations and its establishment usually requires from 400–600 simultaneous stimulations of the normal and conditioning stimulus.

Once established, it has been found that the conditioned reflex seems intermediate between the true reflex and the volitional reaction both as regards the form of the reaction itself and the latent time between stimulation and reaction. Thus, although the initial speed of the conditioned reflex kick is more rapid than that of a volitional reaction, it is still not nearly as rapid as the true reflex. In the case of the conditioning of the pupillary reflex to sound, it was found that the latent time of the true reflex response was from 0.2 to 0.5 seconds while that for the conditioned reflex was more than 1.5 seconds.

It has been indicated that once a conditioned reflex has been established, one may withhold the normal stimulus and obtain the reaction by stimulation with the unusual or conditioning stimulus. Experiments indicate that a great variety of stimuli may be substituted for the normal stimulus in a great variety of different kinds of reflex reaction. A great deal of the early work on the conditioned reflex problem and much of the subsequent work has been done with animals rather than with human subjects. The early work had to do largely with the salivary gland reflex in dogs.

In the study of the reflex action of the salivary gland, it was necessary to perform a slight operation on the dog to change the direction of the salivary duct so that the secretion from these glands was discharged outside of the neck of the animal rather than into the mouth. Hence the drops of saliva could be collected and their frequency and volume recorded during the experiment. The normal stimulus for eliciting the salivary reflex is either the presence of food in the mouth or possibly the odor of food. For this normal stimulus, it has been found possible to use an auditory, a visual or a tactual stimulus in order to obtain a conditioned reflex.

Indeed the conditioned reflex technique has become a favorite method of determining the sensitiveness of animals to different kinds of stimuli. For example, it has been found that if a conditioning sound stimulus of a tone of 425 vibration frequencies per second is used, after many simultaneous stimulations of the normal and conditioning stimulus, the animal will begin to salivate when this tone alone is used. But the animal which gives a conditioned reflex to a tone of 425 vibrations per second may not respond reflexly to one of 500 vibrations per second. The problem, therefore, is to determine the limits of the tones different from the conditioned stimulus of 425 vibrations per second to which the animal responds with a conditioned reflex and these limits become an index of the sensitiveness of the animal to tonal differences.

One difficulty with this technique is that, when the discriminations become difficult, the animals show a tendency to break down. This takes the form of general inhibition in some animals and of extreme excitement in others. Investigators, under these conditions of difficult discrimination have found dogs which exhibited certain symptoms of mental disease strikingly suggestive of mania in some of the animals or of extreme depression in others.

Besides the salivary reflex in animals and the knee-jerk in man, such reflex reactions as the withdrawal of the foot of an animal to an electric shock have been studied. But it has been pointed out that any of these reactions may be under voluntary control as well as being reflexes and that, because of this, one may not be studying a true reflex reaction conditioned to other than the normal stimulus at all. Certainly one can voluntarily kick one's leg or withdraw the foot from a painful stimulus or obtain a flow of saliva by sucking at one's cheeks. The crucial experiment in this respect which proves that one was dealing with a true conditioned reflex was performed some ten years ago. This experiment involved the conditioning of the pupillary reflex, both for dilation and contraction, to a sound stimulus. After such conditioning, the pupil of the eye would either dilate or contract, depending upon which reaction was conditioned in the particular subject, in a constant and unchanged illumination following the stimulation of the sound of a bell. Certainly the pupillary reflex is a reaction which is never under voluntary control and one may be assured that in all of these cases it is a true reflex activity with which one is dealing.

All investigators of these problems report that a conditioned reflex once established, after many repetitions of the normal and conditioning stimulus, is soon lost. It may take a number of hundreds of stimulations to establish a conditioned reflex, but once established, after a few repetitions of the reaction with the conditioned stimulus alone, the individual will then cease to react. This rapid loss of the conditioned reflex has been called *experimental extinction.* Reaction to the conditioned stimulus may be regained by reinforcement with only a few additional stimulations of the normal and conditioning stimulus simultaneously. Experimental extinction is very rapid if there are extraneous and distracting stimuli present during the appearance of the conditioned reflex reaction and if the conditioned reflex is of recent establishment.

At least one conditioned reflex may be pointed out as being normally and almost universally present in man. It is a popular expression that the sight of food makes one's "mouth water." This describes the fact that visual stimulation has set off the action of the salivary glands in conditioned reflex fashion. But the normal stimulus for the salivary reflex is the presence of food in the mouth or possibly the odor of food, although this latter may itself be a conditioned reflex. But many hundreds of times the normal stimulus (food in the mouth) has started the normal reflex in the presence of the sight of food, which is the conditioning stimulus. In time, then, a conditioned reflex has been built up so that the visual stimulus of the sight of food becomes substituted for the normal stimulus and initiates the conditioned reflex. And in this case there is no experimental extinction because there is continual reinforcement with the normal stimulus every time that one eats.

A recent experiment reports the establishment of a secondary as well as a primary conditioned reflex. The experiment was in three stages, the same subjects being used throughout. In the first stage, the subjects were simultaneously stimulated with a blow on the cheek (normal stimulus) and a flash of light (conditioning stimulus) leading to the eye-wink reflex. In the second stage, they were stimulated with an electric shock (normal stimulus) and a blow on the cheek (conditioning stimulus) leading to the hand withdrawal reflex reaction. In the third stage (a test by one stimulation only) it was found that a flash of light alone was the adequate stimulus for the hand withdrawal reflex for 9 out of 15 subjects used in the experiment. Hence, it was demonstrated that there might be double conditioning so that the conditioning stimulus of the first stage might act as a conditioned stimulus in the third stage although it did not occur in the second stage of the experiment at all.

There has been a recent tendency among some psychologists greatly to enlarge the concept of the conditioned reflex and to make such a substitution of an unusual stimulus for the normal stimulus in reflex as more or less synonymous with all learning. Certainly, the conditioned reflex and learning should not be confounded. They are completely different psychologically. In the first place it is possible to condition a response, such as the pupillary reflex, which is a pure reflex activity and which is never under voluntary control. Secondly much greater repetition is needed for the establishment of the conditioned reflex than for learning. Thirdly, the conditioned reflex may be established only in the total absence of extraneous and distracting stimuli which is not true of learning. Fourthly, and again not true for learning, the organism must be in good physical condition if a conditioned reflex is to be successfully established. Fifthly, the rapid loss of a conditioned reflex after a few repetitions described as experimental extinction is completely contrary to what happens to learned material. Finally, and again quite contrary to the conditions of learning, it has been demonstrated that a conditioned reflex may be established only if the normal and conditioning stimulus differ in relative strength. It has been shown that the normal stimulus must be biologically stronger than the conditioning stimulus. Thus there is more biological purpose in the normal reflex dilation or contraction of the pupil of the eye to light than the conditioned stimulus of the sound of a bell. One may be sure, for these reasons, that the conditioned reflex is psychologically quite different from learning.

The facts of the conditioned reflex may be summarized as follows. It has been found that conditioned reflexes may be elicited to any conditioning stimulus providing the normal and conditioning stimulus are given simultaneously a large number of times and provided that the normal stimulus is biologically stronger than the conditioning stimulus. Under these same conditions there is evidence that any reflex may be conditioned and that the reaction may be elicited by a substitute stimulus. It has been found that conditioned reflexes may be established in the animal scale from insects to man. In man this conditioning occurs without awareness on the part of the subject that he is being conditioned. One may presume that it occurs without awareness for all animals below man in the animal scale. The conditioned reflex, however, is of short duration. Experimental extinction soon occurs, after its establishment, unless the conditioned reflex is reinforced from time to time by additional simultaneous stimulations of both normal and conditioning stimulus. And finally, the more complicated the reacting organism from a neurological standpoint, the sooner the conditioned reflexes are lost. Hence, experimentally established conditioned reflexes are maintained longer in the lower animals, with their less complex nervous systems, than they are in man.

How may conditioned reflexes be explained in terms of the anatomy of the nervous system? The reflex arc was described schematically as consisting of a sensory, connecting and motor neuron at a single level of the spinal cord or a single lower brain center below the level of the cortex. The establishment of a conditioned reflex is further evidence that this reflex arc is not an isolated mechanism but that it is intimately connected with or may become connected with many other parts of the nervous system. The simultaneous stimulation of the normal reflex arc in the presence of activity in another neural pathway, which is the neural situation during the establishment of a conditioned reflex, apparently leads to the formation of synaptic connections between this secondary pathway and the motor end, at least, of the normal reflex arc. Hence, after conditioning, a stimulation of either the normal sensory end of the reflex arc or of the sensory end of the conditioned reflex arc leads to nerve energy going across either the normal synapses or the new synaptic connections just established, and in either case stimulating the same motor neurons and thus leading to the same reflex reaction.

Enough has been shown to indicate that although one may define the reflex arc in terms of a specific arrangement of neurons in the nervous system, this is not to be considered an isolated group of neural structures. The reflex arc is intimately connected with the other parts of the nervous system. Thus, although the reflex reaction is inevitable following adequate stimulation, it may be changed in the presence of other muscular or cerebral activity present simultaneously with it. The reflex reaction depends in extent upon the general condition of the individual. And finally, one may substitute a new stimulus, which was not before adequate to call forth this reflex activity, for the normal stimulus, in the establishment of the conditioned reflex.

QUESTIONS

1. What are the characteristics of reflex behavior?
2. What relation exists between consciousness and reflex action? Between voluntary and reflex behavior?
3. Describe the method and give the results and conclusions of the experiment on extirpation of brain and spinal cord in the frog.
4. Reproduce a typical cross section of the reflex arc.
5. On what grounds may we conclude that the reflex arc is not an isolated behavior but is in intimate association with the nervous system in general?
6. What is meant by a conditioned reflex?
7. What are the properties of the conditioned reflex?
8. In what respects do learning and conditioning differ?

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CHAPTER XVI

INSTINCT

The problem of *instinct* has had a long and varied history in psychology. Many years ago, the psychologists took an extreme position in regard to instinct. They said that man was endowed with reason, but that this was denied to animals. To make up for this loss, animals were given instincts instead of reason. Opposed to this extreme position, many present-day psychologists deny the existence of instinct at all either in man or in animals. Undoubtedly the truth lies somewhere between these two extreme positions. Certainly one reason why so many modern psychologists have denied the existence of instinct is because the term has been inadequately defined. In consequence, the facts have been variously described by many writers. For many years there has been a tendency to call any reaction, which could not be otherwise described an instinct. The result has been the gradual collection of many different kinds of reaction into this single category.

Let us consider the following observations made upon the solitary wasp. When the female wasp is ready to lay her eggs, she digs a hole in the ground in which to deposit them. After the eggs are laid in this hole, she searches out a particular kind of caterpillar which she stings in a certain place in the back. The sting enters the body of the caterpillar at a point which is high enough so that it is paralyzed and cannot crawl away, but not so high that any of the vital organs are injured and the caterpillar killed. This still living but paralyzed caterpillar is then carried by the female wasp to the hole in which she has laid her eggs. It is placed inside of the hole and the entrance sealed from the outside with mud. Shortly after this the female wasp dies, before her young are hatched from their eggs. In time the worm-like creatures, which will later develop into wasps, hatch from the eggs. They find food waiting for them in the shape of the paralyzed but still living caterpillar. On this they feed, grow and finally emerge from the hole as young wasps.

These are the facts briefly described. How is this very complicated behavior of the solitary wasp to be explained? Certainly there can be no question regarding the degree of complication. The stinging of the caterpillar so that it is paralyzed, but not killed, assures the young a supply of fresh food when they hatch out of the eggs. This arrangement is a very effective substitute for refrigeration in modern human civilization. And if the caterpillar was merely carried to the nest without being paralyzed, it could force its way out of the hole and escape. On the other hand, if it were stung and killed, it would no longer be fit for food by the time the wasp young hatched out.

An explanation in terms of intelligent behavior does not seem admissible. There are observations which indicate that the solitary wasp does some exceedingly stupid things in this same situation. It has been found that some of the caterpillars are stung too high, so that they are killed; while others are stung so far back that they are not properly paralyzed. But the stung caterpillar is placed in the nest no matter whether the sting has entered at the proper level or not.

Perhaps the least intelligent thing which the solitary wasp does in this apparently intelligent behavior is the following. The great enemy of the wasp is a certain kind of ground ant. It has been observed that it frequently happens, after the wasp has laid her eggs and when she is searching for the caterpillar to be stung and put into the nest, that a female ant slips into the wasp nest and lays her eggs among those of the wasp already there. The female wasp returns, apparently fails to notice the ant eggs, and seals up the nest with the caterpillar, her own eggs and the ant eggs. The ant eggs hatch out some days before the wasp eggs. So the ant young eat the caterpillar, and then eat the wasp young as they hatch out. It is a strain on the imagination to believe that, if the wasp showed enough intelligent foresight to provide a store of food for her unhatched young, she would be so stupid as to expose them to destruction by allowing the ant eggs to remain in the nest, or would fail to perceive that the caterpillar had been killed or that it had been improperly paralyzed.

This complex behavior of the solitary wasp may be partly explained when it is pointed out that the wasp always attacks a certain kind of caterpillar. And it always attacks the caterpillar by swooping down from the rear and landing with its feet just behind the neck of the caterpillar. At the time of the egg-laying season, all wasps of this species are of approximately the same size with some, but relatively little, variation. Also all the caterpillars of this species are of approximately the same size. Given a wasp of this size landing on a caterpillar of its size in such a way that both are facing in the same direction and with their heads on about the same line, it will be found that the sting of the wasp is just about over that part of the caterpillar's back beneath which lies the part of the caterpillar's nervous system which, if injured, renders the animal paralyzed but does not kill it.

Hence, part of this reaction may be explained as due to the relative sizes of the wasp and the caterpillar. What happens to the caterpillar is somewhat in the nature of a biological accident, therefore. What removes the phenomenon from the realm of mere chance is that one must now explain why the wasp always attacks the caterpillar by swooping down from the rear; why it always attacks this particular species of caterpillar, and indeed, why it attacks any sort of caterpillar at all.

And again let us indicate that it is inconceivable that these complicated instinctive reactions are intelligently or consciously directed. If you were given an incubator, the directions for running it and a number of fresh eggs, how would you proceed about hatching them? Unless you had certain very special knowledge, you would probably get the incubator to the correct temperature, put in your eggs, and arrange to maintain the correct temperature. Then you would sit and wait for the eggs to hatch out. If this is all that you did your wait would be a long one, because the eggs would never hatch out. In order to hatch the eggs, it is necessary to turn the eggs every day. The setting hen turns the eggs, and, it will be remembered that such a reaction, which would be called instinctive, is not learned. If the reaction has a background of intelligent conscious direction, then it would follow that the hen; who invariably turns her eggs during sitting, is more intelligent than the human, who would never turn an egg in an incubator, unless he had special knowledge obtained either from observing the reaction of a hen or from information imparted by some other human who had observed the reactions of a setting hen.

On the other hand, these instinctive reactions may be slightly modified to meet special conditions. For example, the different species of birds each builds a characteristic type of nest. The robin builds an upright nest and the oriole a hanging nest, always and invariably. The different species of spiders each build a characteristic form of web. But the birds' nests and the spiders' webs may be modified slightly in each individual case to meet the special conditions of the form of the supporting surfaces, the building materials available and the like. Hence a robin's nest will always be of the upright variety, but its form will vary somewhat depending upon whether it is built in the crotch of a tree or on the top of a shutter against the flat side of a house.

It may be asserted that there is no sharp and distinct dividing line between instinct and reflex. Both are immediate and unlearned responses to the stimulation of the nervous system. Both require an appropriate stimulus to set them going. Both are dependent upon a particular mechanism in the nervous system which may be described in terms of a particular reactive arc. Neither reflex nor instinctive reaction involves any degree of directive consciousness whatsoever.

There are relative differences between reflex and instinct, however, even if no sharp line of demarcation may be drawn between them. In the first place, reflex is a reaction of only a small part of the organism while the instinctive activity is much more nearly the reaction of the organism as a whole. Thus the withdrawal of a single hand to the stimulus of a hot stove would be an example of reflex in the human organism. On the other hand, the much more complex activity of the entire organism in aggression toward a stimulus object or of flight away from it, would be in the nature of an instinctive reaction.

The second relative difference between instinct and reflex has to do with the complexity of the stimulus. For the reflex, this stimulus is simple. The pupillary reflex requires only a change in the intensity of illumination to set it off. The adequate stimulus for the patellar reflex is a light blow on the knee. The sucking and feeding reaction of the new-born infant as an example of human instinctive activity, indicates how much more relatively complex the stimulus must be. Some hours after birth, the placing of the breast of the mother into the mouth of the infant is usually a sufficient and adequate stimulus to set off this instinctive reaction. But it is found that this is frequently not the case. When the normal stimulus fails to set off the instinctive reaction of feeding, the attendant takes the lower jaw of the infant and moves it up and down, while the mother's breast is in the mouth, in imitation of the jaw movements of the normal nursing reaction. If this additional stimulus fails, the procedure is to fill an eye-dropper with warm milk and place it in the mouth of the infant alongside of the breast and slowly force the milk from the dropper into the infant's mouth. In time, as the mouth fills with milk, the infant swallows and this reaction almost invariably sets off the whole instinctive nursing reaction.

The complex stimulus which is adequate for an instinctive reaction has been analyzed in the case of the setting hen. No hen will set on eggs if she has been a layer unless all of the eggs are out of the oviduct. This general physiological condition must first be met as part of the complex stimulus situation. A hen in this physiological condition will set only if her abdomen is stimulated by hard, round, smooth objects of a certain approximate size. If *both* the physiological condition and the condition of the physical stimulation are met, then and only then will the hen set. And the physical stimulation of the abdomen with hard, round, smooth objects of a certain approximate size may be met with any object which fulfills these requirements, such as hens' eggs or ducks' eggs, china eggs or door knobs or large pebbles.

Another difference between instinct and reflex is found in the relative difference in the complexity of the reaction itself. In the case of the patellar reflex, the reaction involves merely the action of the two sets of antagonistic muscles necessary to move the leg. The activity of the nursing instinct in the infant, on the other hand, involves movements of the jaws and tongue and cheeks, of the soft palate and of the whole complicated mechanism for swallowing. Not only are these many movements of many different muscles part of the instinctive reaction but these movements must be highly coördinated with one another to be effective in the whole complex reaction pattern. Not only must each movement be an exactly coördinated one in itself, but all of them must be coördinated in a particular temporal reaction pattern. The coördinated jaw, tongue and cheek movements must be made before the swallowing movements are started. Thus the milk is first drawn into the mouth before it is swallowed.

A fourth relative difference between instinct and reflex has to do with the consciousness which *follows* the reaction. It has been seen that many reflex reactions are accomplished without even a consciousness that the reaction has taken place.

This is true of the normal reactions of the pupillary reflex or the reflex movements of the eyeballs for binocular vision, for example. It seems doubtful if the much more complicated instinctive reaction ever takes place without consciousness that the organism has reacted. One can say with assurance that the instinct is always followed by a *conscious backstroke*,—a consciousness that one has reacted or that one is reacting to a particular stimulus. The clear consciousness during or following certain sexual reactions is evidence of conscious backstroke following instinctive reaction. But this conscious backstroke, which either accompanies or follows the instinctive reaction, is not to be confounded with a directive consciousness preceding the reaction in point of time. Instinct requires no more directive consciousness than does reflex. In the next chapter on emotion, one will find that this question of conscious backstroke following instinctive reaction is of great importance.

And finally, another relative difference between reflex and instinct is in the relatively greater complexity of neural structure for instinct. Figure 98 schematically illustrates two kinds of connection found in the spinal cord. Toward the bottom of Figure A in this chart, the neuron numbered 1 will be recognized as the sensory neuron which has already been described in the last chapter as being the first link in the neural pattern underlying the simple spinal reflex. This sensory neuron makes synaptic connection with the connecting neuron (3) which in turn has synaptic connection with a motor neuron running to a muscle. But besides the synaptic connection between the axon of the sensory neuron which completes the reflex arc at the single level of the spinal cord, this same axon of the sensory neuron also makes synaptic connection with the dendrites of another neuron whose cell body is marked 2 in this chart. This has been called a *spinal sensory neuron*. The axon of this spinal sensory neuron divides into two parts. One part runs down the spinal cord the distance only of a single segment. It then turns at right angles into the gray matter of the spinal cord, where at 4, it forms synaptic connection with a connecting neuron at this lower level. This connecting neuron, in turn, is in synaptic connection with a motor neuron whose axon runs to another muscle controlled from the nervous system at this new level of the spinal cord.

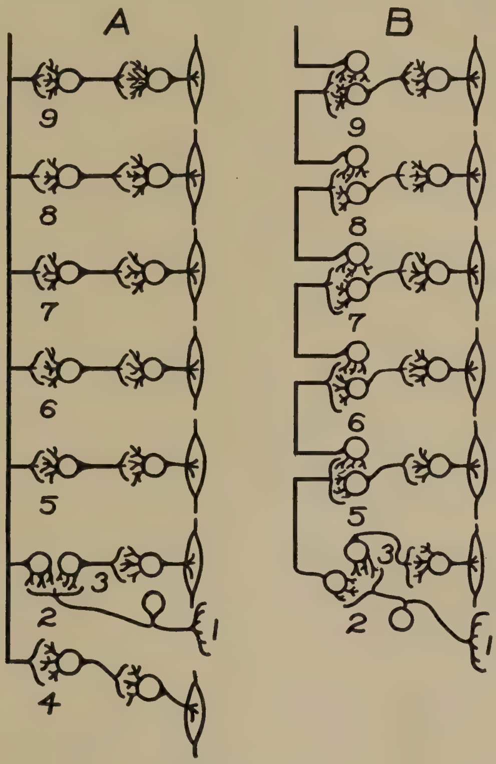

Fig. 98

The other branch of the axon of the spinal sensory neuron runs upward through a number of segments of the spinal cord. At each upper segment of the spinal cord, there is a branch or *collateral* fiber which leaves the main stem of the axon of this neuron. These collaterals each turn at right angles, enter the gray matter of the spinal cord and at 5, 6, 7, 8 and 9, form synaptic connections with connecting neurons at the different spinal levels. Each of these connecting neurons in turn will be seen to form synaptic connection with motor neurons at these different levels. Each of these motor neurons at these different spinal levels has an axon which runs to a different muscle each of which, of course, is at a different level of the body.

Figure B, in this same cut, represents a different arrangement of nerve fibers which also exists in the nervous system but which accomplishes, in fact, identically what is accomplished by the mechanism depicted in figure A. In figure B, number 1 again represents the sensory neuron and the 3 the communicating neuron which is the point of transfer of the normal reflex arc. But the axon of the sensory neuron also forms a synaptic connection, at 2, with the dendrites of another sort of spinal sensory neuron. It will be seen that the axon of this spinal sensory neuron runs up the spinal cord only one segment. It then turns at right angles and forms synaptic connection with two other neurons at this new level. The first of these is a communicating neuron which connects with a motor neuron at this new level. The second is another spinal sensory neuron, whose axon runs upward to the next level of the spinal cord where it makes synaptic connection with both a motor neuron at this new level and with still another spinal sensory neuron whose axon runs still one segment higher in the spinal cord and so on.

The neural mechanism depicted in figure B of this chart is an arrangement by which nerve energy originating in the first sensory neuron is passed in chainlike fashion from one level of the spinal cord to the next higher, but at each level, some nerve energy is shunted off to a communicating neuron which is in synaptic connection with a motor neuron at this new level. The neural mechanism depicted in figure A of this same chart accomplishes the same effect rather more simply through the collateral fibers leaving the main axon at each level and thus forming a synaptic connection with the communicating neurons, and through them with the motor neurons, at each level.

The figure below indicates the position in the spinal cord of some of these neural elements which have been discussed just above. Figure 99 represents three cross sections of the spinal cord at different levels. In this figure, number 1 is again the primary sensory neuron whose dendrites are found in a sensory end organ. There is shown the synaptic connection between its axon for the normal reflex arc (at 3) and with the dendrites of the spinal sensory neuron (at 2). The axon fiber of the spinal sensory neuron is seen to run up and down the spinal cord through the white matter in the posterior part of the cord. At each level a collateral branches out from the main axon, turns inward and (at 5 and 6) forms synaptic connections with communicating neurons which complete the motor end of reaction arcs at these new levels.

One more degree of complication is possible in this neural system. The collateral from the axons of the spinal sensory neuron at each of the new levels of the spinal cord, also can form synaptic connections (as indicated by 7 and 8) with the dendrites of other communicating neurons. The axons of these communicating neurons cross the spinal cord to the other side, but at the same level, where they form synaptic connections with the dendrites of motor neurons on the opposite side of the body.

It will be seen that this neural mechanism gives one the basis for very widespread reactions in the case of stimulation of a single sensory end organ. Thus a stimulation of the end organ at 1 in the chart above can lead to the contraction of many muscles, at different levels of the body and on both sides of the body. Thus, if one considers that the dendrites of the sensory neuron at 1 are located in the patellar tendon, a *light* blow stimulating this sensory terminal would result in the reflex knee-jerk, as has already been found, by excitation cross-

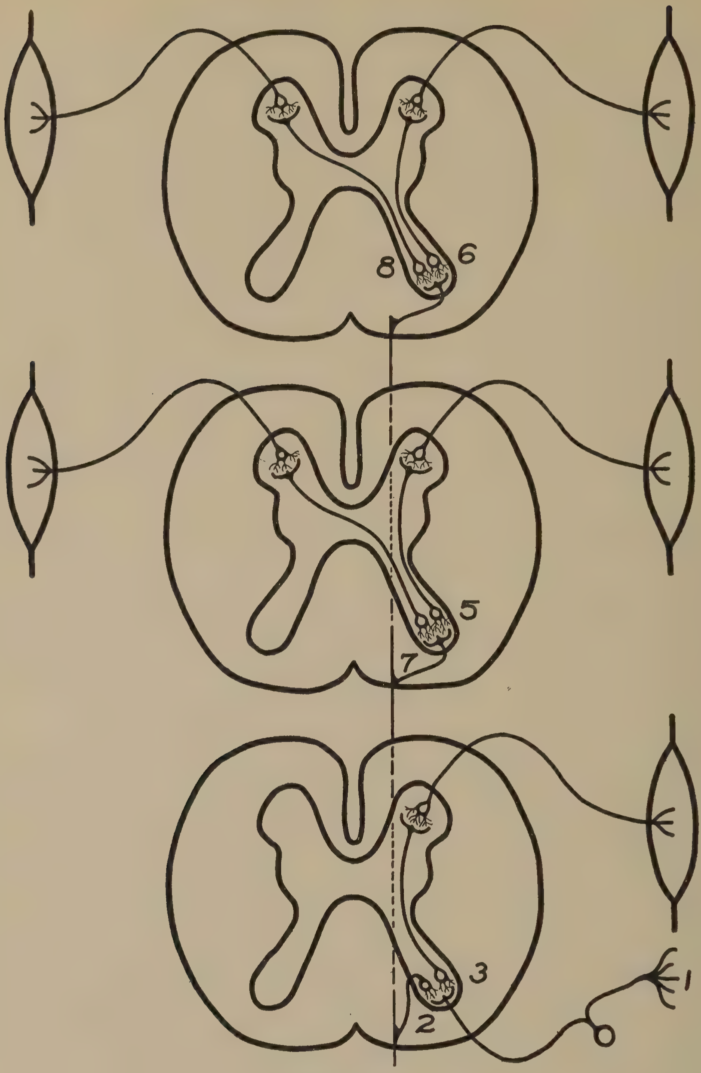

Fig. 99

ing the reflex arc at synapse 3. But if exactly the same sense organ in the patellar tendon is stimulated by a very *intensive* and painful blow, there would be a very much more widespread muscular reaction. Now the nerve energy would get across synapse 2 and be carried by the spinal sensory neuron to the different spinal levels. And by the mechanism discussed above, this nerve energy would be transmitted to communicating neurons at these different spinal levels and hence to appropriate motor neurons at the different levels of the body.

Theoretically, at least, the stimulation of a single end organ on the surface of the body could result in the reaction of every effector in the body. Actually this never occurs, of course. But there has been outlined here a neural mechanism complicated enough and seemingly adequate to account for instinctive reaction. As in the case of reflex, this neural mechanism has been described as if it were located entirely in the spinal cord. This has been done to simplify the description. But many and perhaps the principal neural elements of this mechanism actually lie in the lower brain centers, below the level of the cerebral cortex. The cortex, and therefore consciousness, is only involved in instinct as backstroke—as the consciousness that the reaction is akingt place or that it has taken place.

Thus reflex is seen to depend upon a neural mechanism with a sensory neuron at one end and a motor neuron at the other, with a point of transfer at a single level of the spinal cord. Instinct may have the same sensory neuron at one end of its arc. But at the other ends of the reaction arcs are many motor neurons and between these two ends one finds spinal sensory neurons with points of transfer at a number of different spinal levels. But because of the much greater number of synaptic connections required in the neural mechanism for instinct, the stimulus for instinctive reaction must be more intense or more complex than that required for simple reflex.

There is a great deal of experimental and observational evidence which forms the basis of a number of general statements which may be made about instinctive reactions. These general laws apply to instinctive reactions in both man and animals.

As has been indicated already, the instinctive reactions are always of biological value either for the preservation of the individual or for the preservation of the species. Instinctive reactions of fighting or of flight are examples of behavior which is of biological value for the preservation of the individual. The elaborate behavior of certain birds and other animals before and during sexual reactions is an example of the kind of instinctive reaction which is biologically useful for the preservation of the species.

For examples of biologically useful behavior one turns to the instinctive reactions in insects because these so frequently seem so complicated in terms of human social practices. If you knock over an ant hill, you will discover that the ants will rush out carrying certain small white objects which, on closer examination, will be seen to be small insects. These are the so-called "ant cows" which are a species of insect entirely different from the ant. These are captured by the ants and carried into their nests below ground. Here they are fed by the ants, and in return, the ants drink a secretion which is given off by the "cows." In human terms, this would correspond to the domestication of animals. And the analogy could be carried further. If a cyclone should come, corresponding to one's kicking over an ant hill, the first thing the human would do is exactly what the ant does, namely, attempt to save the "stock." And the capture and care of the "ant cows" by the ant, which is certainly purely instinctive in basis, is as biologically useful as the domestication of animals is for man.

Take another example which emphasizes the purely instinctive character of these highly complex and biologically useful instinctive reactions. If an ant from one colony should approach the hill of another colony too closely, he will be promptly set upon and killed. In human terms this would seem to correspond to the concept of nationalism. But this reaction is purely instinctive in its basis as the following experiment clearly indicates. A number of members of ant colony A were taken and crushed so that their juices could be extracted. These juices of the ants of colony A were sprinkled over a member of ant colony B who was then placed near the hill of colony A. He was accepted as a member of the group and there was no attempt to attack him. Then this ant from colony B who had been sprinkled with the juices of the ants of the other group A was set down near the hill of his own group. He was promptly set upon and killed by the members of his own colony B. The investigator concluded that all of these reactions were dependent solely upon a specific smell stimulus setting off certain kinds of instinctive reaction. The ant accepts any individual who smells like the other individuals of his own colony and attacks any ant who smells differently. Hence this reaction, which is complicated and which seems to be so remarkable when translated into terms of human consciously directed behavior, turns out to be extremely simple. It is a slavish reaction of one sort to a particular olfactory stimulus and an equally slavish reaction of another sort to any other olfactory stimulus.

These ant fights illustrate the second generalization which may be made about instinct. The behavior is an *immediate* reaction of a particular sort to a particular stimulus situation. The reaction follows immediately upon stimulation,—there is no intervening or directive consciousness. And the behavior is seen to be a perfectly slavish reaction. Given a nervous system with certain pathways existent in it, stimulate the sensory end of these reaction arcs, and one may predict the instinctive reaction with the same degree of certainty that one may predict the reaction of the simple reflex.

There is at present a difference of opinion among psychologists regarding the *origin* of these pathways in the nervous system. The older, and probably the most widely accepted view is that these pathways in the nervous system, the presence of the reflex and instinctive reaction arcs, are a matter of birth and of maturation. There has been a tendency to explain the existence of the neural pathways in terms of biological evolution. A particular species is believed to have developed a nervous system containing certain types of pathways in the same way that this species developed a certain type of eye or a certain type of bony structure. And this point of view then states that there is a tendency for these neural structures to be inherited from one generation to the next.

More recently this *innate* origin of the neural pathways has been questioned as the basis for instinct. On the basis of certain experiments, some physiologists and psychologists have insisted that the pathways underlying reflex and instinct are acquired during the lifetime of the individual organism as the result of his own individual experience. These investigators would say that the organism starts with random movements as the result of stimulation and that gradually patterns of reaction, with underlying patterns of pathways in the nervous system, are developed. The experimental evidence seems to be conflicting in regard to the solution of this problem. One cannot as yet definitely state whether the neural pathways underlying instinct are present at birth, as the result of inheritance of a particular neural configuration, or whether they are the result of the experience of the individual. It seems to the author that the weight of evidence still rests with the explanation in terms of an innate origin for the neural configuration. It seems that one is born with certain pathways in one's nervous system which, if stimulated in a certain way, will lead to a particular kind of reaction.

But, and this is the next point to be considered, the particular reaction may only be approximately perfect on the first appearance. The first time the appropriate stimulus sets off the instinctive reaction there are frequently inaccuracies and apparent lack of coördination. For example, a newly hatched chick will peck at a grain of corn which it sees on the ground. It will peck equally positively at a glass bead or at a small pebble or any similar object. Indeed, the chick has to learn to differentiate between the appropriate and the inappropriate stimuli. The first times that the chick pecks, the movements are apt to be exceedingly inaccurate and uncoördinated. It may miss the stimulus entirely or it may hit the stimulus, but fail to seize it or it may get the stimulus into its beak but fail to swallow it. Experimental results indicate that the acquisition of *accuracy* in pecking closely resembles any other learning curve. Nevertheless, the chick does peck at stimulus objects immediately after it is hatched and after all, this is an instinctive reaction, even if it lacks accuracy and proper coördination of movement. There is now some evidence that these pecking movements begin while the chick is still in its shell and that the release from the shell results from these movements and therefore may be considered as something of a biological accident.

Although the instinctive reaction may increase in accuracy and coördination as the result of practice, there is plenty of evidence that the fundamental movements are *unlearned* and that they are due to mere stimulation of certain innate pathways in the nervous system ready to function in a particular way when the appropriate *stimulus* sets off the particular reaction. Some years ago the author visited a commercial rat colony on a hot sultry summer day. Here white rats were bred for sale for experimental purposes. The breeding females were kept with their young in separate cages until the young were weaned. Then the young rats were placed in rearing cages to be developed to a saleable age. Rats born within a three-day period only were placed in separate rearing cages. These cages were approximately five feet long, three feet wide and two and one-half feet high with wooden sides and with wire screening over the top. Something over 200 rats were placed in each rearing cage; some idea may be obtained of the conditions of relative overcrowding from that figure.

As we walked through this colony, it was observed that rats, apparently dead, were hanging from the wire screens covering every one of the cages. One surmised that the rats had jumped up to get air and had caught their noses between the mesh of the wire and had been suspended there until they had died. This was mentioned to the director of the colony, who said: "But we practically never have a rat die. Those hanging rats are asleep." And he scratched the nose of the first rat and then one after another and each would open its eyes, throw back its head and drop to the floor of the cage as lively as one could wish. Each rat had jumped up and caught its upper teeth over a strand of the wire and then gone to sleep.

This observation was described to several directors of large rat colonies who said that they had never before heard of such a reaction in the rat. This was naturally true because the so-called "standard" cage for rats is long, low and narrow with a wire front. And usually only two or at least only a few rats are placed in such a cage. The "standard" conditions varied from those found in this particular rat colony. There was much less crowding, and under the standard conditions, with the wire front and the wooden top to the cage, there was no opportunity for the rat to hang by its teeth. The stimulus conditions for calling forth this instinctive reaction seem to be complex and multiple: (1) the physical conditions of the form of the cage must be suitable; (2) there must be overcrowding; (3) both the temperature and (4) the humidity must be high. If these four stimulus conditions are satisfied, apparently any rat will sleep by hanging by its teeth.

It is hard to conceive that each group, born within a three-day period, would all have intelligently worked out this solution of the sleeping problem. It is even more difficult to conceive that in each group there would have been one or more "genius" rats who worked out the solution and that the rest of the groups copied their reactions. One can only believe that this is an unlearned reaction which has its basis in certain neural pathways present at birth. But these pathways will never function to give this complicated pattern of reaction until the complicated stimulus conditions are present to set off the response.

It may again be pointed out that the rat's reaction of sleeping by hanging by its teeth is biologically purposeful like every other instinctive reaction. In the first place, this means of sleeping gets the rat off the floor so that he will not be trampled upon and thus disturbed by the other rats. And secondly, suspended in this way, the air can get to all sides of the rat at once. Thus this sort of reaction brings about the same results as man's invention of the net hammock for use in the tropics.

Still another generalization which may be made about instinct is that the reactions are all approximately *similar* for members of the same species of animals. All chicks peck and all young mammals nurse, each species having its own appropriate instinctive reaction.

But, on the other hand, the instinctive reactions are *different* for different species of animals. After all, chicks do peck and mammals do nurse shortly after birth. There may even be widely different reactions for the male and female of the same species for the same instinct. The different reactions of the male and female landlocked salmon during spawning illustrate this generalization.

The landlocked salmon live in summer in the deep pools of certain fresh water lakes. The spawning season is in the fall of the year. At this time, the male salmon comes to the pebbly bottoms of the shallow streams which flow into the lake. Each male salmon then cleans all refuse from the pebbles in a certain spot and pushes the pebbles to one side to make a "nest." This cleaning and the making of the nest is a very fatiguing affair. After the male has rested, he swims away and returns accompanied by a female whom he escorts to the prepared nest. Each male returns to the nest which he has prepared. The female settles over the nest and lays her eggs. Once this has been completed, she swims away. This is her entire contribution to the mating. The male then settles over the eggs and fertilizes them. He then moves the pebbles until he has covered up the fertilized eggs and then he swims away. In the spring the eggs hatch out and the very small salmon young swim out through the cracks between the pebbles. They spend their early life in the shallows of the small stream in which they were hatched. This description of the spawning of the land-locked salmon indicates how different the reaction of male and female may be in the same species and for the same instinctive activity.

Another generalization which may be made regarding instinct is that these reactions are *slightly modifiable,* but on the other hand, that they can be modified only with difficulty. Practically all of the experimental evidence with animals indicates that little or no modification can be accomplished for instinctive reactions. For example, young song birds of several species have been reared together without either effecting the notes or calls of the other. Birds of one species have been hatched and reared in a nest of another species of a different type. But when they have matured and built their own nests, these have been of the type of their own species. Apparently the nests are unmodified by the lifelong contact of the makers with a nest of another sort. Dogs and other animals have been kept from birth in double cages so arranged that a male and a female are in the two halves of the cage. The floors of these cages were electrically wired so that either animal could touch any part of his cage without closing the electrical circuit, but if the animals touch one another through the separating wire partition, both received a severe electric shock. It was found that, in spite of a lifetime of experience of avoiding one another, that once the two animals were sexually matured and were together there was no apparent modification of their instinctive sexual reactions.

On the other hand, there is evidence that many reactions in man, which have an instinctive basis, may be modified although this modification is accomplished with much labor and with great difficulty. The development of articulate speech in man is an example of great individual modification which is built upon a small but entirely essential basis of instinctive reaction. The instinctive basis is small compared to the final product and the language development may be exceedingly varied depending on the particular individual experience of the particular human. Thus the small instinctive basis for articulate speech may be modified into English, French, Japanese or what not besides.

Many years ago the author spent considerable time trying to develop articulate speech in a chimpanzee and an orang-utan by using the most approved articulation methods employed in teaching deaf to speak and in the correction of speech defects. The result was that each animal finally learned to articulate several simple sounds such as "mama." But these articulate sounds were never used as language. The sounds would be made by these animals only if they were forced to repeat them under considerable restraint.

On the other hand, any normal child will develop articulate speech. The difference would seem to be that articulate speech has an instinctive basis in man and that this instinctive basis for articulate language is lacking in animals even so close to man in the animal scale as the orang-utan and the chimpanzee. During the early weeks and months of its life, the young human child exhibits a number and a variety of sound reactions. These reactions of crying and cooing and the like would seem to be the instinctive basis for the future development of language in man. On the other hand, the adult chimpanzee makes only four sounds of which each is only part of an expression of a specific emotion. And three of these four sounds are modifications of a bark which merely vary in intensity. The chimpanzee seems to lack the small but highly necessary basis of instinctive reaction which forms the background of the extensive modification for the development of articulate speech in man.

The modification of instinctive reactions may be accomplished in either of two ways. The modification may consist in the inhibition of the normal instinctive reaction. Hence a stimulus which was at first effective to call forth a particular reaction is no longer adequate to call forth this same reaction. For example, dogs can be trained not to chase cats or not to bark at strangers. There is an interesting example of the modification, inhibition and control of an instinctive reaction in man because this modification is accomplished before the instinctive activity actually appears. The instinctive sexual reactions in man develop only with the maturity of the sex glands at puberty. But long before this time, and indeed almost from birth in our present society, there has been training in modesty which has prepared an inhibitory modification of the sexual instinct when it appears.

The other way of modifying instinct is to substitute some other reaction in the stimulus situation in place of the normal instinctive behavior. A single isolated observation from the literature, which may not be true at all, illustrates this sort of modification exactly. It was observed that a newly hatched chick pecked at a caterpillar. It happened to be a bad tasting caterpillar and the chick stood on one foot and wiped its bill vigorously with the other. It is reported that a short time afterwards this same chick saw another caterpillar of this same bad tasting sort. Instead of the normal pecking reaction, the chick substituted the reaction of wiping its bill.

One difficulty with accepting this example as a real modification of instinct by the substitution of some other reaction to the stimulus situation, is that the substitution was accomplished on the basis of only a single experience. Any one who has raised children will know how difficult it is and how many repetitions are necessary to either inhibit a reaction or to substitute another activity for certain instinctive reactions in the infant or the young child. For example, the instinctive reaction in the young child is to reach for and take anything which catches his attention and interests him. It takes a long time to modify this instinctive reaction and to develop other socially accepted reactions which are in conformity with the notion of private ownership of property.

It was once believed that instincts were found only in the lower animals and that in man reason and intelligence were substituted for them. Psychologists today believe, or at least those psychologists who believe in the existence of instinct at all, that there are probably more instinctive reactions in man than are found in any particular species of lower animals. The list of instinctive reactions in man, including those reactions like articulate speech which have an instinctive basis, is long. Such activities as feeding after birth, smiling, fighting and sexual reactions seem to have a purely instinctive basis in man.

There are two ways of looking at instinct. If instinct is viewed primarily from the point of view of its underlying neural mechanism, one falls more or less easily into thinking of it as a chain of reflexes. From this point of view, each reflex seems to be the stimulus for the setting off of the next reflex. On the other hand, one may view instinct primarily from the point of view of a more or less complicated stimulus situation. If this view be taken, instinct becomes thought of more in the category of *drive* or *motivation* rather than as a chain of reflexes. From this latter point of view instinct becomes the way the animal reacts to a stimulus situation which is biologically important for the preservation of either the individual or of the species.

In spite of criticisms from many quarters, the retention of the term and the concept of instinct seems highly desirable for modern psychology. Experimentation is difficult in this field. But there are certain *fixed patterns of behavior* which are too complicated to be explained in terms of simple reflex but which seem to be unlearned and dependent upon a certain complex stimulation of certain pathways in the nervous system established at or even before birth. These are the instincts. In this chapter there has been a tendency to throw the emphasis upon the reactive or drive aspects of instinct rather than upon the underlying neural mechanism.

QUESTIONS

1. On what ground may the behavior of the solitary wasp be classified as instinct?
2. How is instinct related to reflex?
3. What is the relation of consciousness to instinctive behavior?
4. What are the characteristics of instinct?
5. How is the origin of instinctive behavior most acceptably explained?
6. How may instincts be modified?

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CHAPTER XVII

EMOTION

The topic of *emotion*, like that of instinct, has been a battle ground of opinion among psychologists. This situation is partly due to the fact that there are two aspects of emotional experience and some psychologists have tended to emphasize unduly the first at the expense of the second, while others have unduly emphasized the second aspect at the expense of the first.

In the first place there is a conscious aspect to emotion. We feel angry or we are conscious of fear. This conscious aspect of emotion is universally attested to by introspection. The introspective reports invariably contain such words as *pleasant* or *unpleasant*. Consciously, emotions seem to be compounded partly of what have been called *feelings*, which are described either by the words pleasantness or unpleasantness.

Besides the conscious aspect of emotion there is also the *reactive* side. When one is angry, he finds that he is gritting his teeth and clenching his hands. When he is pleased, he finds that he is smiling. Practically all investigators working in the field of emotion have been willing to recognize both the conscious and the reactive phases of emotional experience. Also, these investigators have recognized that emotion does not happen spontaneously. It is necessary to have a stimulus to set the conscious and the reactive phases of emotion going. One is never just angry—he is always angry at some stimulus object. One never just runs away from fright—again, he runs away from some stimulus object which is said to be fearful. There are then three phases of emotion which have to be considered in a study of this topic: (1) the stimulation; (2) the emotion as conscious process; and (3) the reactive aspect of emotion. Keeping these three aspects of emotional experience in mind, a persistent problem for psychology has been to decide upon the temporal order with which these three phases of emotional experience occur.

All psychologists would agree that stimulation comes first. But they are not agreed regarding the temporal sequence of the conscious and reactive aspects of emotion. The traditional and common sense view asserts the following temporal order: (1) that one is stimulated; (2) that this stimulus arouses an emotion in consciousness and (3) that the presence of this particular emotion in consciousness leads to appropriate reaction. From this point of view, the reactive phase has been called the expression of the emotion. The classical temporal order, (using a classical example) is that (1) we see a bear; (2) we are afraid and (3) because we are afraid we run away, our heart beats faster, we have "goose flesh," our hair stands on end, and what not besides.

Other psychologists would reverse the temporal order of the last two phases of emotion and would make the conscious phase dependent upon the reactive rather than the other way about. They would insist that the temporal order in emotion is: (1) stimulation; (2) this stimulation of certain pathways in the nervous system sets off a whole complex series of reactions in a purely reflex or instinctive fashion and (3) the conscious backstroke that we are reacting in this particular way *is* the conscious emotion. Thus in the example of the bear, they would say that (1) we see a bear; (2) this stimulus sets off, in a purely reflex or instinctive fashion, a complex reaction pattern of running away and the like, and (3) the consciousness that we are reacting in this way,—this conscious backstroke, *is* the fear. Thus the classical order would say that we cry because we are sad; smile because we are happy. The newer point of view would insist that we are sad because we cry; happy because we smile.

On first acquaintance, the newer point of view toward emotion would seem to be at variance with the observed facts. Much is to be said for the simplicity of this point of view, however, which makes emotional consciousness merely a backstroke of a complex reaction pattern of an instinctive sort. Indeed one psychologist has gone so far as to attempt to relate emotions and instincts in pairs so that each instinctive reaction has its own different emotional backstroke. Perhaps one reason why popular introspection almost universally says that emotion comes before the reaction is due to the fact that it is the conscious rather than the reactive aspects of the emotional situation which usually gain the center of attention. Certainly the discussion of instinct in the previous chapter lays what would seem to be an adequate basis for considering emotion from this newer point of view. This discussion of instinct has emphasized the necessity for stimulation; the complexity of the reaction pattern and the universality of the conscious backstroke following the reaction. Indeed the present discussion of emotion has been left until this place so that the reader could have before him this previous discussion and description of instinctive reaction.

Thus, if one will accept the point of view that the conscious emotion is merely the conscious backstroke of an instinctive reaction complex which immediately follows stimulation, then no further discussion of underlying neural mechanism is necessary. The alternative is the acceptance of the classical view toward emotion—that the emotion in consciousness comes first and that the presence of the emotion in consciousness leads to its expression in terms of a particular reaction complex. In this case, we would have to add another chapter to the first part of this book in which would be described the conscious emotions which would be the basis of these reactive expressions. In the present text, we shall take for granted that the second point of view more nearly corresponds to the truth than the classical point of view.

Try to simulate anger. Look at a friend intently and build up all of the reactions which usually accompany this emotion. Contract your eye brows, grit your teeth intensively, clench your fists, make your breathing faster and shallower, tense the muscles of your abdomen. And finally walk aggressively and menacingly toward your friend. Build up the expression of anger as well as possible and it can still be predicted that you will not be angry. Does not this failure to produce the emotion of anger by building up the reactions constitute a grave criticism for the acceptance of the instinctive basis for emotion? The failure would force one to reject this newer view except for the fact that it is impossible to build up the *entire* reaction complex for anger or for any other emotion.

What you have done when you try to simulate anger, and all that you can ever do, is to build up that part of the complex reaction which is under voluntary control. You have controlled the skeletal muscles so that they conform to the reaction pattern underlying anger and no more. For example, you have not controlled and you cannot control the rate or the strength of your heart beat. But a change in heart beat is always present for anger. You have failed to obtain the conscious backstroke because you have failed to build up the complete reactive pattern.

The situation is even much more complex than one supposes because there is now a great deal of evidence that the functioning of certain glands, and especially some of the ductless glands, always accompanies and plays an important part in the reaction complex which is basic for certain emotions. Certain investigators have found that in fear and anger in animals there is always an increase of the amount of adrenin in the blood stream. Adrenin is the secretion of the so-called *adrenal glands.* These are ductless glands located near and above the kidneys. It will be remembered that, inasmuch as they are ductless glands, the secretion is placed directly in the blood stream when these glands are active and that this secretion is carried by the blood to other parts of the body. The adrenal glands are never under voluntary control. One cannot say: "adrenals, secrete" and have them become active in the same way that one can clench one's fists when one wishes. The nerve supply to the adrenal glands is through the autonomic or sympathetic nervous system. Not only are these glands never under voluntary control, but also one is not aware directly of activity of the adrenal glands. How many readers knew of the localization of these glands or even of their existence before they had read this paragraph? Certainly one acquires this knowledge by study and not from any conscious experience of their reaction.

It has been discovered that the presence of an increased amount of adrenin in the blood stream rapidly leads to very wide-spread and important reactions. Adrenin even in small amounts causes: (1) faster heart beat; (2) an increase in breathing; (3) stoppage of digestion; (4) redistribution of the blood in the body. There is less blood in the digestive tract and relatively more blood in the central nervous system and the muscles; (5) rapid liberation of sugar from the liver and the presence of greater quantities of sugar leads to two more effects as follows. (6) The increased amount of sugar in the blood leads to greater muscular strength and (7) it partly neutralizes the formation of fatigue poisons in the muscles. Finally, (8) the presence of increased adrenin in the blood causes the blood to coagulate more rapidly.

Here is indeed a complicated and wide-spread series of reactions simply due to the presence of increased amounts of adrenin in the blood stream. It is hardly surprising that your attempted simulation of anger did not lead to the actual emotion when this great complex was not part of the reaction pattern. And the reaction of the adrenal glands is a purely reflex activity following and requiring stimulation. The secondary effects of the presence of increased adrenin in the blood stream on the action of heart and lungs, on the distribution of blood in the body, on the digestive reactions and on the action of the liver are also reflex in character. But the whole reaction, taken as a reactive pattern, is too complicated to be considered simple reflex. It can be considered more readily in the more complex reactive category which has been called instinct.

And like every other instinct, these reactions are highly purposeful for the preservation of the individual or of the species. In terms of primitive reaction, anger leads to fight and fear leads to flight. All of the reactions due to adrenal secretion are useful in either case. The heart beats faster leading to better blood supply. There is increased breathing and hence better oxidation of the blood. The amount of blood is increased in the muscles and the central nervous system, where it is useful in either flight or fight, and is decreased in the digestive system where it is least useful in these situations. Digestion stops because it requires blood which can be more useful elsewhere. The secondary effects of the action of the liver in liberating increased amounts of sugar into the blood stream is also highly purposeful. Thus the increased muscular strength makes for better flight or fight and the overcoming of fatigue poisons makes one able to fight or flee for a longer time and at a higher continued level of efficiency. Finally the more rapid coagulation of the blood may be the means of saving the animal from bleeding to death from wounds received either in flight or fight. It can be seen that there is a real physical basis for the apparent reserve powers which are so frequently observed under emotional stress. These reactions all form an important part of the pattern of the reaction complex for either of the emotions of fear or anger. And they are all reactions of an instinctive or reflex sort and thus are never under voluntary control.

In this discussion only the adrenal glands have been treated. This is because we happen to know so much about the effects of stimulation of these particular glands and so little about the effects of many of the other glands. It is certain that some of the other glands of the body also contribute to the reaction complex of emotion. Indeed it is not at all improbable, as we gain more knowledge of the effects of the functioning of other glands, that we shall find that the glandular contributions to the emotional reaction patterns are much more important than the contributions of all of the other structures of the body combined.

The problem of the control of the emotions also contributes evidence of the probable correctness of the view that the conscious emotion is merely a backstroke of an instinctive pattern of reaction. There is a popular belief which says that, if you should feel yourself becoming angry, you should relax and count ten slowly. This is good psychology. By relaxing one is able to break up a part of the instinctive reaction complex which is the basis for that emotion. It is equally good psychology to whistle as one goes by a cemetery at night. Again one has changed the reaction complex which is fear. Just this same sort of principle is used in the treatment of certain mental diseases. In the treatment of acute cases of *mania*, it is a frequent technique to place the patient in a hot bath and keep him so immersed for hours and even days. Mania is an abnormal appearance of the complex reaction of anger. In anger, there is always intense contraction of the skeletal muscles. Hot water tends to relax this muscular contraction. So by this means, this part of the reaction complex for anger is eliminated, the reactive pattern for anger is broken up to this extent and the anger disappears as emotion.

From this point of view the really brave man in a war is not the one who has no fear at all but rather the one who has intensive fear but who goes over the top just the same. The man without fear is merely fortunate in this situation. For him the stimulus situation is not adequate to produce the particular reflex and instinctive pattern of reaction which is this emotion. The other, braver but far less fortunate individual, has the appropriate reaction pattern produced by the same stimulus situation, but he has been able to break up some of the constituents of this pattern. And such a man will then find, once the pattern of reaction has broken up, that the emotion itself has disappeared.

But only those parts of the emotional reaction complex which are normally under voluntary control, can be eliminated. This means that the control of emotions is accomplished only by eliminating the reactions, or by substituting different reactions of the skeletal muscles, because these particular effectors alone are under voluntary control. We have seen, then, that it is not possible to build up an emotion by the appropriate reactions of skeletal muscle alone. These play only a part in the total reactive complex of emotion. But, on the other hand, the control of emotions involves primarily just the control of these skeletal muscles because by such control the total pattern of reaction complex is broken up. And it is fortunate that once this reaction complex has been destroyed, the emotion itself disappears.

It must be pointed out that the pattern of the reaction complex may vary from one individual to another and it may vary in the same individual from time to time for the same emotion. In the first place, there may be considerable overlap in the reaction pattern for very different emotions. It has already been seen that the adrenal reaction and its various consequences occur in such widely different emotions as fear and anger. One may run as rapidly toward some object of his love as one runs away from the traditional bear. One may cry for joy as well as for sorrow. Both glandular and muscular reactions may vary in the reaction pattern of what one or another observer will report as the same emotion. And the contributions of both sorts of effectors may vary in what the same individual will report as the same emotion from one time to another.

The conclusion to be drawn from this is that there is no "standard" pattern of reaction complex which represents each particular emotion at all times and for every individual. A number of well known investigators have described facial and postural expressions which they have alleged were characteristic of particular emotions. On the basis of these descriptions, it has been alleged that one may judge a particular emotion in another individual by observation of facial and postural expression alone.

In order to test the truth of this assertion, several examples of facial expression of emotion from a well known system were shown to a large number of students who were asked to check the best descriptive name for each in a list which contained the "correct" names of these emotions mixed with many others. The result was that only a very small proportion of the students reported the "correct" name for each of these emotions. For practically every emotional expression shown, every name on the list was checked at least once. In a second stage of this experiment two degrees of suggestion were introduced. In the lower degree of suggestion, the "correct" name was given in each case to the observers who were asked if the face shown was an adequate representation of this emotion or not. Under these conditions of slight suggestion, the number of "correct" answers increased very greatly and the expression was almost unanimously judged to be an adequate representation of the emotion named. A second degree of suggestion was introduced in which the parts of the expression were analyzed for the observers and the purpose of each part (mouth, eyes, nose or brow) of the expression for this particular emotion was described. In this second situation the percentage of "correct" answers was as great but no greater than for the lower degree of suggestion. In both cases of suggestion "Horrified" was judged "correctly" in 98 per cent of the cases; "Disgusted" in 99 per cent and "Bewildered" in 96 per cent; "Contemptuous" in 99 per cent and "Reverential" in 87 per cent of the cases.

To another group of observers, the same faces were shown but now false suggestion was given. The face which was alleged to represent "Bewildered" was shown, for example, and the observers were told that it represented "Reverential." Or the face for "Contemptuous" was said to represent the reaction of the emotion "Disgusted." Under these conditions it was found that the false suggestion was almost as adequate as the true suggestion in the alleged recognition of emotion by facial expression alone. Thus the actual face for "Contemptuous" was voted an adequate representation for "Disgusted" by 97 per cent of the observers. And under the higher degree of false suggestion, 95 per cent of the observers reported that the expression for "Reverential" was an adequate representation of "Bewildered."

Experiments have been performed using the moving picture technique of emotional expressions in infants. Each moving picture showed the actual stimulus situation, such as sticking a pin into the skin of the infant, and the following emotional reaction. These moving pictures were shown to a large number of observers including doctors and nurses trained in children's hospitals, who should certainly be expected to have been trained in observing such reactions in infants and consequently to know what particular reactions were. It was found that, if the stimulation part of the pictures be eliminated and the reaction part alone shown, then the observers might report almost any emotion for each picture. The percentage of correct answers was small. On the other hand, if the stimulus situation was shown before each reaction, the percentage of correct answers increased to almost absolute correctness. But, if the films were cut and reassembled so that each reaction picture was preceded by an incorrect stimulus situation, one obtained an equally large percentage of *incorrect* judgments of the emotion.

Accordingly the judgment of emotion by facial or other motor expression alone seems to be determined largely by the suggestion given by the stimulus situation and seems to have relatively little basis in the actual pattern of contracted and reacting muscles. Hence one may believe that the perception of emotional states in others by their expression is much more dependent on the stimulus situation than on anything characteristically intrinsic in the facial expression or other external aspects of the reaction.

There have been many experiments which have attempted to measure the degree or intensity of an emotional experience. Attempts have been made to correlate the intensity of an emotion with changes in breathing, heartbeat and blood pressure. It can be said that most, if not all, of these attempts to measure the intensity of an emotion by the extent of some physiological reaction have failed. In recent years a method has been devised for which such measurement of emotional intensity is claimed. This is the galvanic skin response. It was found that during emotion there frequently occurred changes in the resistance of the skin to the passage of a constant electric current. It was alleged that the degree of the change of this electrical resistance was an indication of the strength of the emotional experience. Recent experiments indicate that such changes in resistance of the skin to an electric current occur with all kinds of psychological processes, emotional or not. Frequently the observer will introspectively report emotional experiences which do not seem to be accompanied by any change in the skin resistance. Hence the measurement of emotion, other than by an introspective report of the observer, is a problem still to be solved.

One difficulty with the solution of the problems of emotion is that this is a field in which experimentation is difficult. If one tries to make an introspective analysis and description of emotion, he finds that he is observing only the intellectual aspects of the experience and that the emotion itself has vanished.

In the study of the reactive aspects of emotion another difficulty presents itself. It is perfectly possible to bring an observer into the laboratory and so arrange stimulus conditions as to create emotional experience. But one finds that if this stimulus is repeated a number of times it may soon lose its ability to set off the emotional reaction. This is evidence that there is very rapid and very complete emotional *adaptation* to any particular stimulus situation. This was the experience of many soldiers during the war. Many were terrified at their first experience at the front. It may be said with perfect safety that no individual felt entirely at ease and perfectly comfortable when he was brought up to the front for the first time under heavy fire. But very soon, usually within a few minutes, one became adapted to this situation so completely that the emotion disappeared entirely and the adequate stimulus of a few minutes ago no longer set up the particular reaction pattern of that emotion. In place of this reactive pattern, if one thought about it at all, there remained merely the intellectual aspects of the situation. For example, one judged whether a given shell would strike close by or not; or whether a given shell was a high explosive or a gas shell.

In some recent experiments made in an effort to find stimulus situations which would be effective time after time, only two artificial situations were discovered to which, for some individuals, there did not seem to be any emotional adaptation. Many different situations were tried and emotional adaptation was rapid and complete in all but two. The first of these situations to which there was no emotional adaptation was one involving sexual reactions. The second situation consisted in the nude subject being stretched on a table, completely covered with a sheet, and having white rats running about on the top of the sheet. There were some individuals, but not all, for whom this experience called forth intensive emotional reaction time after time without any apparent emotional adaptation.

We are now faced with the problem of answering the question as to how many human emotions are there? Various writers have suggested different lists, some with only a few emotions, others with many. These lists are based upon introspection and upon observation of adult emotional reactions. Recently an investigator has approached this problem from the point of view of determining what stimuli will elicit reactions, which appear to be emotional in the very young human infant.

He tried a great variety of stimuli and found that only a very few of them set off emotion reactions. Thus, if the very young infant is stimulated with a loud and sudden noise, he gives a characteristic reaction which may vary in detail from one infant to another, but which shows the same general pattern of reaction for all. Also if one holds an infant several inches above the mattress of its crib and then allows it to fall by suddenly withdrawing the supporting hands, it also gives a characteristic reaction which appears to be emotional. And the reaction following the loss of support seems to be exactly similar to that following stimulation with a loud sudden noise. This similar reaction pattern to such very different stimuli has been characterized as *fear.*

If the infant is stimulated by having its arms held to its sides and its head and body so held that it cannot move, it exhibits a pattern of reaction which seems to be emotional and which is different from the reaction pattern characterized as fear. Also a pattern of reaction identical to that following physical or bodily restraint is exhibited by the infant when it is hungry. This investigator has called both of these reactions *anger.* The only other stimulus which elicits a reaction in the young infant which seems to be emotional in character is obtained by gently stroking the skin on any part of the body. The reaction to this stimulus has a pattern quite different from those either for fear or anger. This reaction has been characterized by this investigator as *love,* but might be better called *pleasure.*

Thus it was found that only five stimuli were effective for eliciting emotional response in the young human infant. And in two cases, the same pattern of reaction occurs following very different patterns of stimulation. Hence, this investigator has concluded that there are only three major primitive human emotions—fear, anger and pleasure.

But the literature is full of assertions regarding all sorts of primitive fears. A primitive fear of snakes is often quoted. Also primitive fears of furry animals, of feathered birds, of lightning and what not besides, are often given and are almost universally believed. Snakes, rats, rabbits and pigeons were placed in the infants' cribs during this experiment and in no case was the presence of these stimuli adequate to elicit emotional response. Indeed a pigeon with its wings clipped and its feet tied, when introduced into the crib, would flutter in a fashion which might be expected to set off a reaction of fear. Nothing of the sort happened. The conclusion must be that primitive fears of birds, animals and reptiles simply do not exist.

But then this investigator went on to discover that it was easily possible to *condition* an emotional reaction to any stimulus whatsoever. For example, a rabbit would be placed in the crib of the infant. The child would be interested but would exhibit no emotional reaction at all. When they were sure that the infant was attending to the rabbit, for example, when the infant would reach for the rabbit, the experimenter would make a loud sudden noise behind the infant. This noise is one of the normal adequate stimuli for calling forth the fear reaction and the infant would exhibit the normal reaction for fear. The next time the infant reached for the rabbit, the noise would be repeated, again eliciting the fear reaction in the normal way. After a few repetitions of the normal stimulus for fear, and the child's subsequent normal reaction, in the presence of the rabbit as stimulus, it was found that a conditioning was accomplished so that the presence of the rabbit alone now became an adequate stimulus to set off the fear reaction.

On the basis of these experiments, one may believe that the fear of many people of lighting must thus be considered a conditioned emotional reaction. It was set up because lightning so frequently is followed by the sudden, loud noise of thunder. It is the thunder which is the original adequate stimulus for the fear reaction and the lightning must be looked upon as a conditioning stimulus.

It was found that almost any stimulus could become adequate to elicit fear if conditioned by the presence of one of the normal stimuli for setting up this reaction. It was found possible also to uncondition the emotional reaction to any stimulus for which conditioning had been accomplished. Thus an infant, conditioned for the fear reaction to a rabbit, would exhibit this reaction pattern if the rabbit was even brought into the room. Then the rabbit would be brought into the room, far from the conditioned infant, at meal time, and the child would only be fed in the presence of the rabbit. In time, under these conditions, the infant would exhibit no emotional reaction and would eat with the rabbit at this distance. Then gradually, the rabbit would be brought closer and closer to the infant until it could again be introduced into the crib at meal time without calling forth the fear reactions. But it was found that it required many more repetitions to uncondition a subject, who exhibited a conditioned fear response to an unusual stimulus, than it took to condition this reaction in the first place.

If one adopts a point of view toward emotion according to which only a very few stimuli are normally adequate to elicit emotional reactions but in which, through conditioning, any stimulus may easily become adequate to call forth an emotional reaction, we then have a simple explanation of both the large number of fear-evoking stimuli in most individuals and of the abnormal fears in some individuals. These abnormal fears have been called *phobias*. Most of these abnormal fears seem curious to the normal person, but they are very real indeed to the individual experiencing them. Phobias may be such things as the fear of open places or the fear of closed places. For example, a very well known American poet is afraid to go more than a mile from his home and he has not been beyond that distance for many years. There is the case of a psychologist, who was an extremely prolific writer, publishing one or more books every year. He had an abnormal fear of open places. Each day, when he took exercise, he would walk round and round the city block in which he lived, never crossing a street and keeping close to the house side of the pavement as he walked. And because of his abnormal fear, when he moved from one house to another, he went on a dark night in an automobile with all of the windows screened. Had this individual been transported to the center of an open field, it is probable that there would have been so intensive an emotional reaction that serious effects might have resulted.

An abnormal fear of cats is another frequently exhibited emotional reaction. One may believe that all of these and many more different kinds of abnormal emotions are conditioned in more or less the same way that the infant was conditioned to exhibit a fear reaction to the rabbit. And in the same way, it would seem possible to recondition the subjects suffering from these abnormal fears so that this unusual stimulus situation would no longer be effective. But this reconditioning is found difficult under experimental conditions, and in the cases of real abnormal fears, the individual is so strongly conditioned that great labor and time would be necessary to correct the abnormal reaction.

In the case of the *insane*, the actual stimulus to which the emotional reaction is conditioned may be purely imaginary. One aspect of insanity may be a loss of the feeling of reality. Thus sometimes objects which actually exist may lose their reality, and on the other hand, purely imaginary ideas may become very real indeed. Hence an insane patient may have a phobia that someone is trying to kill him by throwing poison powders through the window of his room. Any other idea, equally fantastic to normal individuals but perfectly real to the patient, may become an adequate conditioned stimulus to call forth emotional reactions.

The older literature of psychology is replete with references to *temperament.* A very old classification lists four different temperaments for which the time honored names are sanguine, choleric, melancholic and phlegmatic. It is doubtful if any such classification actually adds a great deal to our understanding of human nature, because individuals do not seem to fall into only one or another of the categories except in some very few exceptional cases. And most individuals seem to exhibit one attitude at one moment and another temperament at the next. Many wives will report that their husbands may be choleric, or quick to anger, before their morning coffee, but that they are sanguine, or happy and hopeful, after breakfast.

It is possible that the four temperaments may be analyzed in terms of the three major emotions which have been discussed above. It is possible that either through conditioning or because of individual differences in the ease with which particular patterns of emotional response are aroused one has here the basis for these so-called temperamental differences. Hence the phlegmatic person is described as one in whom there is little emotional response of any kind. It may be in such an individual that no stimulus calls forth any of the three typical patterns of emotional response with any degree of facility. For the choleric temperament it may be that this individual is one in whom the pattern of response for anger is readily called forth. Thus an individual who has a low threshold of the fear response would be called melancholic. And finally one for whom the love and other pleasant responses were easily called forth would be spoken of as sanguine.

Such an analysis would account, for example, for the common observation of the irascibility of the chronic dyspeptic. Such an individual finds himself in a vicious circle. In the discussion of the adrenal glands above, it was pointed out that one of the reactions following adrenal activity was the stopping of the process of digestion. Hence, if the dyspeptic becomes angry during or just after meals, the accompanying adrenal activity will stop digestion which, of course, increases the dyspeptic condition. The dyspeptic condition in turn acts as an irritant which lowers the threshold for emotional reaction so that he becomes angry more easily, which again increases the irritant and so on. Any physical irritant, such as eye strain or the constant pain of a chronic bad tooth may so lower the threshold of emotional reaction as to cause a change in what may be considered as the fundamental temperament. The elimination of the irritating cause may again change the temperament of the individual by raising the emotional threshold which thus requires a greater intensity of stimulus to be effective for initiating the emotional reaction.

Finally, what may be considered the neural mechanism underlying emotional reactions? The entire neural mechanism for instinctive reaction, described in the previous chapter, certainly plays a part. The contribution of the sympathetic or autonomic nervous system lying outside of but alongside of the spinal cord, has been emphasized as important. It is this neural mechanism which conducts nerve energy to so many of the glands and other internal organs of the body, the activity of many of which proves to make such an important contribution to the reactive pattern of emotion. It is this sympathetic nervous system, for example, which we have found supplies nerve energy to the glands. There is also a good deal of evidence that a center inside of the brain plays an important part in emotional reaction. There is evidence that disease of this sub-cortical center leading to its partial destruction may lead to profound emotional disturbances and to great changes in emotional reaction.

In conclusion, then, there has been an effort to explain emotional activity as a form of instinctive reaction. Both require a stimulus to set them going. Both seem to have their basis in the activity of approximately the same neural mechanisms. Neither involves directive consciousness or consciousness preceding the reaction. Both involve an adjustment of the organism to its environment and both are therefore purposeful for the preservation of the individual or of the species.

On the other hand, there are these possible differences between emotion and other types of instinctive reaction. In the first place, there seems to be a relatively greater participation of glandular activity in the reactive pattern for emotion than for the other types of instinctive activity. And secondly, although both emotion and the other instinctive reactions have a conscious backstroke so that the individual is conscious that he has reacted or that he is reacting, this subsequent consciousness seems to be more prominent for emotion. But both of these differences are matters of degree and not differences in kind. Thus it seems reasonable to consider emotion merely as a special kind of instinctive reaction.

QUESTIONS

1. What three problems are immediately involved in the study of the emotions?
2. What is the temporal order of events in emotional experience?
3. What particular kinds of reaction are of the greatest importance in emotional behavior?
4. What is the relation of the adrenal glands to emotion?
5. Distinguish between the voluntary and involuntary components of the emotional reaction complex.
6. On what grounds do we attribute emotional experience to others?
7. What is the relationship of physiological states to the consciousness of emotion?
8. What is meant by emotional adaptation?
9. What is known of the emotions of children?
10. How is emotion related to instinct?

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CHAPTER XVIII

VOLITION

Induce someone to act as subject in a very simple experiment. Ask him to coöperate but not to "fake" the results under any circumstances. Have him stand with his feet close together, not with the toes turned outward, and with his eyes closed. Then stand in back of him and give the following instructions: "You are to take a deep breath and exhale slowly. If you feel as if you were going to fall over backward, do not try to stop yourself from falling. I will surely catch you. But you must seriously attend to what you are doing." If this subject carries out your instructions, you will discover that he will sway slightly backward and forward. Each time that the subject begins to sway backward, say to him: "Now you are beginning to fall backward." You will observe that the backward sways will become more pronounced if the subject is really coöperating and very frequently he will actually fall over backward so that you will have to catch him.

The psychologist would submit this demonstration as an example of *volitional reaction* on the part of the subject. But the criticism will at once be raised that the subject reacted by falling over backward not because he willed it but frequently in spite of his will. It may be pointed out that the term "*volitional*" was used and not the term "*willed*" in describing this behavior. In an earlier chapter it was pointed out that attention cannot be thought of as a mental searchlight which may be turned now on this and again on some other process in conscious experience. In that chapter, the conditions of clearness were described in exactly the same way that elsewhere the conditions of sensory quality were described.

There is a similar parallel in the case of volition. Modern psychology has rejected any concept of a will which is of the nature of a mental faculty which directs one's reactions irrespective of anything else in one's mental makeup. How modern psychology defines volition may best be approached by contrasting it with reflex and instinct both of which have already been treated in previous chapters. Reflex is a reaction set off by the stimulation of certain reactive arcs in the central nervous system for which there is a point of transfer at a single level of the spinal cord or lower brain centers. With reflex there is frequently not even consciousness that one has reacted. Instinct is a reaction set off by the stimulation of certain reactive arcs in the central nervous system in which several levels of the spinal cord or lower brain centers are involved. With instinct there seems always to be a conscious backstroke. But in neither reflex or instinct is there any consciousness *before* the reaction begins. In both cases the reaction follows immediately upon stimulation without any intervening consciousness between stimulation and reaction.

One can summarize the temporal order of events, then, as follows. For reflex the temporal order is stimulation, followed by reaction, with a subsequent consciousness rarely occurring. For instinct the temporal order is stimulation followed by reaction and in turn followed by consciousness. The psychologist would define volition as a reaction in which an appropriate consciousness *preceded* the reaction so that in this case, the temporal order is stimulation followed by consciousness and this consciousness is in turn followed by reaction. For volition *consciousness intervenes between stimulation and reaction.* The definition in terms of this changed temporal order of the appearance of consciousness and reaction is the only sensible way of approaching the problems of volition.

Modern psychology, then, is not interested in the age-old problem of "*free will.*" There is a popular belief that indicates that one performs a certain act because he "wills" to do it.

Anyone accepting this point of view would probably be content to accept the assertion that, for volition, the conscious idea precedes the reaction. There is no quarrel about this but they would go much further and insist that the idea in consciousness *causes* the reaction. Such a statement leads one into certain fundamental philosophical difficulties which seem too technical to be discussed in the present place. Suffice it to say that the psychologist is willing to leave the possible causal relationship between conscious idea and subsequent movement an open question and rather is content to define volition merely in terms of a particular temporal order in which consciousness precedes the reaction.

Let us return to the demonstration of getting a subject to fall over backward, which has been called an example of volitional reaction. This particular sort of reaction has been called *suggestibility.* In the first place there was stimulation; the subject was told that he might fall backward and this suggestion was repeatedly given to him when he was told that he was falling over backward. Secondly, there was this idea in consciousness and this was repeatedly reënforced by the suggestion of the demonstrator. Finally and last in the temporal order, there was the motor reaction of the subject. This is volitional behavior, then, simply because the conscious idea of falling over backward came before the reaction of falling. Really the only essential difference between the definition of volition in terms of a temporal order and the popular concept of this reaction has to do with how the idea gets into consciousness The man on the street believes that *he* puts this particular idea into consciousness. The psychologist may not be concerned especially how the particular idea gets into consciousness so long as it is there and so long as it is followed by reaction. He would account for the appearance of a particular idea in consciousness in terms of the ordinary laws of association and the like. Psychology would further emphasize that volition never occurs spontaneously any more than does reflex or instinct. There is always some stimulus which impinges on the sensory end of the reactive arc in all three cases,—reflex, instinct and volition—which leads to reaction.

Try another demonstration of suggestion. Get a subject to stand with one arm rigidly outstretched shoulder high before him. Indicate one object on each side of the room. Have the subject close his eyes and think intently of one object or the other. In time it will be observed that the hand will move or drift in one direction or the other. If the subject really has been thinking continually of one or the other object, one can be sure that he has been thinking of that object on the side toward which the hand has moved. Here is an explanation of the so-called "mind reading" of some stage performances. Such demonstrations are nothing more or less than "muscle reading" of this kind.

Facts such as these have led some psychologists to believe that every idea in consciousness tends to express itself in motor reaction. This can be described in either of two ways. It has been said that there exists *ideo-motor force*, that every idea expresses itself in appropriate motor reaction. Or it has been said that every idea has two phases, a conscious phase and a motor phase. Examples of reaction accompanying an idea in consciousness are numerous. It will be observed that one tends to smile when one sees another smile. One can demonstrate this sort of suggestion readily. Merely yawn several times before a group of people and it will be observed that a number of others will yawn within a very short time. In this sort of suggestion, the basis is the perception of an external stimulus and this form has been called *sensory-motor suggestion*. It is highly probable that all *imitation* has its basis in nothing more or less than sensory-motor suggestion. The stimulus which sets off the imitative reaction is the perception of a similar reaction in some other individual. Imitation may be thus classed as a form of volitional response.

A somewhat higher form is *ideo-motor suggestion* in which the physical stimulus is less prominent and which implies a highly conscious idea. For example, ask someone to describe a spiral staircase and he will almost invariably move his hand in a spiral fashion. Or ask someone to describe a Van Dyke beard and this description will be almost invariably accompanied by the appropriate gesture.

The principle of ideo-motor suggestion has been successfully employed in the treatment of certain types of mental disease. Its employment has been particularly useful in the treatment of cases of *hysteria*, a condition in which the patient believes that he has some malady but for which there is no actual physical basis. Such an individual may believe that his arm is paralyzed, for example. In such a case movement of the arm is quite impossible such as it would be if an actual paralysis were present. The condition is a perfectly real one although the basis is purely imaginary. The condition is due to an idea in consciousness and it will not be corrected until this idea is eliminated from consciousness and another one substituted for it. It seems worth while to outline the procedure in a particular case in some detail.

Suppose a patient comes in with a report that he is unable to move his right arm. Examination shows that there is nothing wrong with the muscles or the nerves supplying energy to them. For example, it can be demonstrated that the reflexes are present. From this and from other evidence, one concludes that the apparent paralysis is hysterical in origin. The physician now proceeds to trick the patient so that, by suggestion, he may substitute some other idea, namely, that of the ability of the patient to move his arm. If he succeeds in substituting this other idea clearly and permanently enough in consciousness, a cure will have been accomplished and the apparent paralysis relieved.

Many years ago the author saw such a cure made in a clinic by suggestion in the hands of a celebrated nerve specialist. He remarked to this patient, after he had examined him: "You are a very lucky man." Naturally this statement rather startled the patient who had considered himself very unlucky indeed. The doctor then went on as follows: "You are lucky because you came to me inasmuch as I can cure you. You are lucky that you came to me today and not a year ago. Because during the year I have invented a new kind of electric current which will cure just your kind of case. But you have to take a chance. I can only use this type of current once on you. Its use cannot be repeated. If it is on a fraction of a second too long or too short, it will not work and then I can do nothing more for you. But my assistant and I will use the utmost care that the electric current shall be turned on exactly the right length of time. Are you willing to take this chance? If so, I am sure that I can cure you right here and now with a single treatment."

Naturally this talk to the patient emphasized clearly the idea of a cure. By asking the patient to decide himself whether or not he would submit to the treatment, he was induced to think about the matter and hence the doctor could be sure that the new idea would be clearly in consciousness. But it will also be noticed that these instructions emphasized that the electrical treatment could be used only once. By this the physician was protecting himself. Very often in cases of hysteria the "Cure" is only temporary and the patient would return almost daily for "treatment."

After some consideration the patient decided he would take the chance—anything was better than this paralysis. The physician then made an elaborate series of measurements of the "paralyzed" arm and then an elaborate calculation, presumably from these measurements. Both the measurements and the calculations were really entirely meaningless, but at the end, the physician told the patient that they indicated in this case, that the electric current should be on for exactly $17\frac{1}{5}$ seconds. Such an odd number is much more impressive than a round number such as 15 or 20 seconds would have been.

In the meantime, the assistant had been setting up an electrical machine exactly like those found in almost any well equipped physician's office.

The doctor then repeated his instructions to the patient in order to obtain further emphasis of the idea of cure. He then cautioned his assistant to be extremely careful to start and stop the machine exactly on command. Then the electrodes were placed on the patient so that an electric current of painful intensity would pass through the effected arm. The physician took a stop watch, started it as he gave the signal "go" when the current was turned on. Then he looked over the stop watch at the patient's face until he believed that the patient had received enough stimulation. He then shouted "Stop" and the current was turned off. The physician then made a show of looking at the stop watch and remarked: "Just right—exactly 17⅕ seconds. Now, Mr. X, lift your arm." And the arm went up indicating that the patient had been "cured" of his paralysis.

The reader may remark that this is merely play-acting on the part of the physician. This is granted, but play-acting is necessary to get across the adequate suggestion in cases of this sort. The method has been successful in effecting permanent cures in individuals suffering from purely imaginary ills. The ill has its basis in an idea in consciousness and the cure is effected by substituting some other idea through suggestion. Some years ago a French pharmacist had a great vogue in Europe and America by curing ills by the simple method of having the patient repeat a simple formula a number of times each day. Certainly cures were effected, but equally certainly these were only accomplished in hysterical patients whose ills were purely imaginary. If one will repeat often enough and with proper clearness of the idea in consciousness the formula, "Every day in every way I am getting better and better" he will find that he is getting better and better *provided nothing was the matter with him in the first place.* But one hastens to add that such imaginary ills may be as serious as real ills for which there is an organic or physiological basis.

Perhaps the clearest and most outstanding example of ideomotor suggestion is to be found in *hypnosis*. In introducing this topic one hastens to say that there is probably no topic in the whole field of psychology about which there are more popular misconceptions. In the first place, the hypnotist has no particular "power" over the subject who is hypnotized. Such a power over the subject implies that the will of the patient becomes subservient to the will of the hypnotist. Actually the patient hypnotizes himself and the hypnotist's contribution is largely to make the conditions optimal for the patient to hypnotize himself. This is accomplished by the patient thinking of one idea to the exclusion of other ideas. By suggestion, the hypnotist merely reinforces that particular idea in consciousness.

There are three sorts of persons who cannot be hypnotized. The first are the feeble minded who are not able to get any idea clearly enough in consciousness to lead to the hypnotic trance. The second include those suffering from certain kinds of insanity in which there is a very rapid flight of ideas. For these individuals no idea remains long enough in consciousness for the individual to hypnotize himself. The third group are ones who actively resist hypnosis by continually and rapidly changing the idea in consciousness. Except for these three groups everyone else can be hypnotized if they are willing to coöperate and follow the instructions of the operator.

The idea most frequently employed in hypnotizing is that the patient is to go to sleep. In time the subject will go into a hypnotic trance, the external characteristics of which resemble true sleep. But recent experiments on the patellar reflex indicate that the reactions during the hypnotic trance closely resemble those in the normal waking state and that both are different from the reflex reactions during true sleep. The knee jerk is of much greater extent during either the normal waking state or the hypnotic trance than during normal sleep. Also the number of voluntary responses to a bell signal again indicates that the hypnotic trance is different from true sleep but that the trance results are similar to those obtained in the normal waking state.

Once the subject has been induced, through suggestion, into the state of the hypnotic trance, he may be made to give various reactions, again through suggestion. In this respect one may point out another popular misconception which is very widespread. In spite of detective novels and short stories, no subject may be hypnotized, and while in the trance, do anything against which he would have moral scruples in the waking state. Thus if a hypnotized subject should be given a dagger or even a rubber dagger and told to stab someone to death, he would come out of the trance unless he would be perfectly willing to stab this person in the normal waking state. But the subject may be given a cane and told it is a fishing rod and go through all of the motions of fishing. Any such complex idea introduced by suggestion into consciousness will result in the appropriate pattern of reaction. The hypnotized subject may be thrown into a state of catalepsy in which there will be complete contraction and rigidity of all of the skeletal muscles. Here is evidence that the reactions of the muscles normally under voluntary control may be produced through hypnotic suggestion.

Also some glandular reactions such as shedding of tears and sweating may result from such suggestion. Changes may be effected in the sensory system as well. In some cases it is possible to produce loss of sensitivity to pressure (*anesthesia*) and even loss of sensitivity to pain (*analgesia*) by hypnotic suggestion. Major surgical operations have been performed while the subject was in a deep hypnotic trance with the suggestion of anesthesia and analgesia. Actually the subjects report that there is no pain under these conditions and they exhibit none of the facial grimaces or respiratory changes which usually accompany pain. Certain purely non-voluntary reactions such as pulse changes accompanying pain are usually present at these times but even they are very much reduced. There is evidence that cold sores may be induced and digestive reactions invoked by hypnotic suggestion. *Hyperesthesia* or increased sensitivity has been claimed for hypnosis. For example, it has been claimed that subjects could read type in the trance so small that it could not be read in the waking state. However, recent experiment under controlled conditions indicates that sensitivity is not increased under hypnosis.

Certain individual differences in what is remembered of events of the trance state after awakening have been noticed. Some subjects apparently remember a great deal of what happened during the hypnotic trance while others remember little. For most subjects there is a total amnesia of what happened during the trance. Although none of this material can be recalled, there is evidence that some memorial effect is produced. Experiments have been conducted on the development of reaction habits with training only during the trance. While none of these habits could be recalled after waking, it was found that the subjects could relearn the habits in the waking state approximately 50 per cent more rapidly than others who had not been given the previous trance training.

In this connection there is the interesting phenomenon of *post-hypnotic suggestion.* During a trance, a subject will be told that he is to perform a certain act at a certain later time. He will then be awakened and will have no memory of his instructions. But at the suitable time he will perform the task with the belief that the idea came spontaneously into his consciousness. There is experimental evidence that the strength of such post-hypnotic suggestion follows the usual curve of forgetting, being rapid at first and then declining more and more slowly.

This is supposedly a chapter on volition, yet only problems of suggestion and hypnosis have been discussed thus far—

problems which are popularly but erroneously believed to involve a reaction against one's will. However, it has been pointed out that the only acceptable psychological definition of volition is one in terms of a reaction for which one of the temporal antecedents is an idea in consciousness. Suggestion and hypnosis have been employed as examples of this simplest sort of volitional behavior. The idea in both cases precedes the reaction. We have tried to emphasize that this idea is dependent upon stimulation and that it does not occur in consciousness spontaneously. In both suggestion and hypnosis a single idea is in consciousness without any opposing ideas. The presence of the single idea in consciousness leads at once to the appropriate reaction. Such a situation has been called *singly determined volition.*

Such singly determined volitional reactions occur frequently in normal life and are by no means confined to the special cases of hypnosis and suggestion. If, in the middle of a lecture, the professor should suddenly give a short loud shout it is sure that every student would promptly look up from his notebook. This reaction would follow the appearance of a new perceptual idea in the center of consciousness unopposed by other ideas, thus leading to the appropriate reaction. If you are walking with a friend who trips, you promptly put out a helping hand to keep him from falling. This is a singly determined volitional reaction resulting from a particular conscious perception. There is nothing "reflex" or "instinctive" about this reaction in the least, although it is usually described in these terms. Perhaps, due to some association, you may suddenly remember that you had promised to telephone a friend. You promptly go to the telephone. Here, an unopposed idea has preceded the appropriate reaction. But the idea has arrived in the center of consciousness by a perfectly explainable series of associations, it will be found. Being unopposed, the idea leads at once to the appropriate volitional reaction.

We must now consider those cases in which there is a conflict of ideas involving a decision, which on that account may be said to be based upon *volitional choice.* This has been called *multiply determined volition,* because each reaction is determined by a choice among several opposing ideas or groups of ideas. Let us illustrate by an actual case.

Some time ago a college girl came to the Psychological Clinic seeking vocational advice. She was a young Russian girl of great beauty, and as was discovered from the application of psychological tests, she was possessed likewise of a high degree of intelligence. She came from an exceedingly superior Russian family, and at the time of the revolution, passed through a number of harrowing experiences. Among them she had seen her parents killed. As a result of this series of shocks she was naturally in a highly nervous condition, but there was evidence that she had improved considerably during the last few years, and there was every expectation that she would be completely cured with time, rest and proper handling. She had succeeded in getting out of Russia and was working her way through college.

She expected to go to a medical school and she came to the Psychological Clinic to ask whether or not she was fitted for this kind of career. In the course of conversation, it became evident that she really wanted advice as to whether or not she should marry a fine young chap who had proposed to her. She had many acquaintances in college, but no one to whom she felt close enough or in whom she had enough confidence to ask for this advice. Apparently she felt she would rather go to a stranger than to one of her acquaintances.

In the course of her examination in the Clinic the suspicion that she had a certain small amount of Negro blood was aroused. Just at this time, a blood test had been announced by which it was claimed that the blood of different races crystallized in different ways. Hence, from a blood sample it was possible to determine very definitely whether or not there was any racial mixture in this case. A sample of her blood was obtained on the pretext of determining her nervous condition and arrangements were made for her return to the Clinic in a week. The blood sample was sent to the Medical School for the crystalline test of racial mixture and the report came back that she had at least one-eighth Negro blood.

Here are the facts. Let us suppose that you are the Director of the Psychological Clinic and that this girl is coming back for her second appointment in one hour. What do *you* do in this situation? To aid you in making this volitional choice, let us list a number of alternative possibilities and point out the consequences of each.

A. In the first place you can tell her the findings of the blood test. There is reasonable assurance that she does not know of this admixture of Negro blood. Remember her general condition and her present highly nervous state. It is almost certain that this information suddenly imparted to her will be a mental shock of such magnitude that, in her condition, it may lead to a complete mental breakdown. In this case she is apt to end her days in an institution for the insane.

B. It is possible to withhold this information about her racial mixture. In this case she is apt to marry the young man. This gives a certain probability, although the chances are very small, that she may produce a child with very decided Negroid characteristics. This shock would be even worse for the girl than the shock following the telling her of the truth. Besides one must think of the consequences on the husband and particularly on the child itself in such a situation. By this course one is possibly condemning three people to a life time of misery.

C. It is possible not to tell the girl but to call in the young man, tell him the truth and let him decide what he will do in the situation. He may decide to marry the girl anyway, and in this case, if she should give birth to a child with Negroid characteristics, the effect on herself and on her child would be equally as great. There is little room in our modern American social scheme for such a family as this. If the young man decides not to marry her, she will probably worry as to why he has so suddenly dropped her acquaintance and stopped seeing her. This worry may have serious consequences.

D. One could advise her against marriage because of her nervous condition. One could point out that it was safer for her to go into the medical career for which she has such an excellent intellectual endowment. But she is a girl of great charm and beauty, who because of her medical background, will certainly know within a few years that she is in physical condition to marry. Such an alternative is largely in the nature of putting off the final decision and of taking it out of your hands. The girl is a type who will almost surely have plenty of opportunities to marry.

E. You can advise her against marriage and emphasize the fact that she should go into medicine. And further you can suggest that she return to the Clinic from time to time so that you may hope to break the news of her racial mixture at some later time when you can lead up to the matter more slowly and when you believe that she is in better condition to stand the shock.

These are only a few of the possibilities but they are sufficient for our purpose. Remember that you are to consider yourself the Director of the Clinic. What are you going to tell this girl when she comes in one hour from now? Remember that her sanity may depend on your decision if you adopt one alternative. Remember that the happiness of a husband—either this man who wants to marry her now or some other man in the future—and of an unborn child may depend upon your making certain other of the possible decisions. But in these latter cases, recognize that the chances of her having a child with decided Negroid characteristics are small but perfectly possible. Make your decision as to what you will tell this girl without reading any further in this test.

Once your decision has been made, it is possible to add one more fictitious factor to the case. Suppose that you are now told that the young man who wants to marry this girl is your own brother? What effect does this new information have upon the decision which you have made already?

Let me assure you, and you can verify this for yourself if you will think back over the various stages leading to your volitional choice, that your decision has its basis in your own background of past experience. If you should come from a part of the country in which racial mixtures are condemned, it is probable that this situation presented nothing of a problem at all. It became a singly determined volitional reaction. As a student once said: "Of course, you tell her and also warn the man." And when it was pointed out that this course would almost cause insanity in the girl, he remarked: "But what difference does that make, she is a Negress after all!"

In this country our attitude is determined by a definition that a person is a Negro if he has any known Negro blood. In Brazil, however, the definition is changed so that a person is defined as white if he has any known white blood. The proportions or kinds of other racial bloods in the mixture are of no consequence. In Brazil, then, this decision would equally be a singly determined volition. In that country it would not even present a problem. For most of us, however, solution of the choice of alternatives in this situation presents a real problem, and requires genuine consideration.

As a matter of fact, the story is entirely fictitious. Such a blood test of racial admixture does not exist although one was announced some years ago, but has proved to be of no value. The story has been introduced to give a problem which might be expected to have considerable emotional overlay, about which you would be forced to make a volitional choice that would be multiply determined for many readers, and which presents a problem involving serious consequences. The choice is made in the accepting of one of the several conflicting alternatives. Once this particular idea stands in the center of consciousness, the motor reaction appropriate to the idea follows at once. There cannot be a more adequate demonstration that, in volition, the *idea precedes the reaction.*

We must now consider the mechanism for such a volitional choice. One explanation that has been advanced emphasizes the fact that every idea has both a conscious and a motor phase. This explanation draws a parallel between the field of consciousness and the field of vision of the single eye. In the field of monocular vision, it has been pointed out already that clear vision exists in the region of the fovea alone and that as the image moves from the fovea toward the periphery of the retina, vision becomes less clear. The theory would say that only the conscious phases of an idea are present when it is not in the clear center of consciousness. But when an idea establishes itself in the center of consciousness, both the conscious and the motor phases are effective. Such an idea will then be expressed by the appropriate reaction.

Fig. 100

The theory forces one to explain why and how a particular idea gets to the center of consciousness in order to exhibit both the motor and conscious phases. This is really the problem of volition because once the idea is in the center of consciousness the reaction follows as a matter of course. Figure 100 may be helpful in this explanation. An idea anywhere in consciousness (represented by the circle) will exhibit its conscious phase, more and more clearly as it approaches the center of consciousness (marked x). In singly determined volition, let us say that an idea is already in the center of consciousness. Another idea comes into consciousness, such as the shout during the lecture or your remembering to telephone a friend. There is no opposition to this new idea and so it comes at once to the center of consciousness and thus at once exhibits its motor phase.

In normal consciousness, however, one is aware not only of the idea claiming the center at any given moment but also of other less clear ideas in the conscious fringe, each of which has a potential claim to the center of consciousness, which can be demonstrated by its displacing the idea already there, thus leading to its own appropriate reaction. Hypnosis can be explained in terms of a single idea getting so clearly in the conscious center that it stands alone in consciousness, at a time when all the other ideas on the fringe or periphery are eliminated. Hence, under hypnosis, there is no conflict with the single idea in the conscious center. It remains there exhibiting its motor phase and expressing itself in appropriate reaction until it is replaced by some other idea, introduced by suggestion, which in turn exhibits its own appropriate motor reaction. Thus, under hypnosis, one stays in apparent sleep until, as the result of suggestion, one gives the required reaction of fishing or what not besides.

For multiply determined volition the situation is different as is illustrated in figure 101. Again the circle illustrates the field and the x the center of consciousness. In the illustration of the Russian girl above, five alternatives from A to E were indicated, each in conflict with every other one. These are represented by the letters in the periphery of the conscious field. While each of these ideas is in the periphery and thus tending to exclude every other one from the conscious center, no decision will be reached and no reaction will occur. Eventually one or another of these ideas will get into the conscious center for a long enough time to exhibit its motor phase and thus lead to volitional expression. The theory implies that the particular one of the several conflicting ideas which reaches the conscious center will be that one which has the greatest number of associations or the greatest apperceptive background of past experience.

Thus there exists an explanation of the most intricate sort of volitional choices in terms that are not in the least mystical and which are in harmony with other psychological processes. It may well be that the apperceptive backgrounds of several conflicting ideas are so balanced that no one of these is able to get into the center of consciousness and remain there long enough to be expressed in reaction. This is typical indecision and in this case no reaction will eventuate. Then something may happen which adds to the apperceptive background of one of these ideas. A decision, with its appropriate reaction, occurs. We attempted to illustrate this, in the example above, when the reader was told that the man who wished to marry the Russian girl was his own brother.

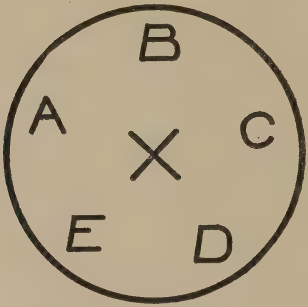

Fig. 101

If such a psychological explanation of volitional behavior is not accepted, one is forced to either of two extreme alternatives. One is forced to the belief that each individual has complete control over which of several ideas may get into the conscious center. One may *will* which of several alternatives one will accept even though the weight of associations and of apperceptive background may be strongly in favor of some other alternative. Thus, although one's entire background is in the direction of the acceptance of one particular idea, the individual may will to accept another alternative. Such a point of view implies that there is some sort of a *prime mover*, some mechanism or faculty of willing which is entirely independent of all the rest of the psychological system of the individual. It implies that volitional reactions may be spontaneous and that they are in no way affected by the past experience of the individual or by the stimulation of the moment. A discussion of some of the objections which might be raised against this viewpoint would carry us beyond the scope of the present text. It may be pointed out that many philosophers and some psychologists have accepted this point of view.

At the other extreme lies the purely mechanical explanation. According to this, volition is conceived in the nature of a reflex arc. Reflex itself is described in the purely mechanical terms of the stimulation of a particular arc in the nervous system and the subsequent stereotyped reaction. Instinct is likewise explained in purely mechanical terms with the recognition that the neural arcs are more complex. And finally these psychologists would insist that what has been called volitional reaction is again to be explained in the purely mechanical terms of the stimulation of a particular reflex arc in the nervous system. From this point of view, man is to be conceived as a sort of automaton—what one puts into the nervous system, be it reflex or at the volitional level, one gets in the way of response. From this point of view, what goes on in consciousness has no relation whatsoever with the reaction. The reaction is determined only by the kind of nervous system and the stimulus which impinges on it at the moment. And indeed some psychologists would go so far as to deny that there is any consciousness at all.

Very much simplified and in schematic fashion, the neural pathways underlying volition are given in figure 102. Two cross sections of the spinal cord are shown and above these are indicated the medulla oblongata or brain stem and the cerebrum or brain proper, both in cross section. Numbers *1* and *2*

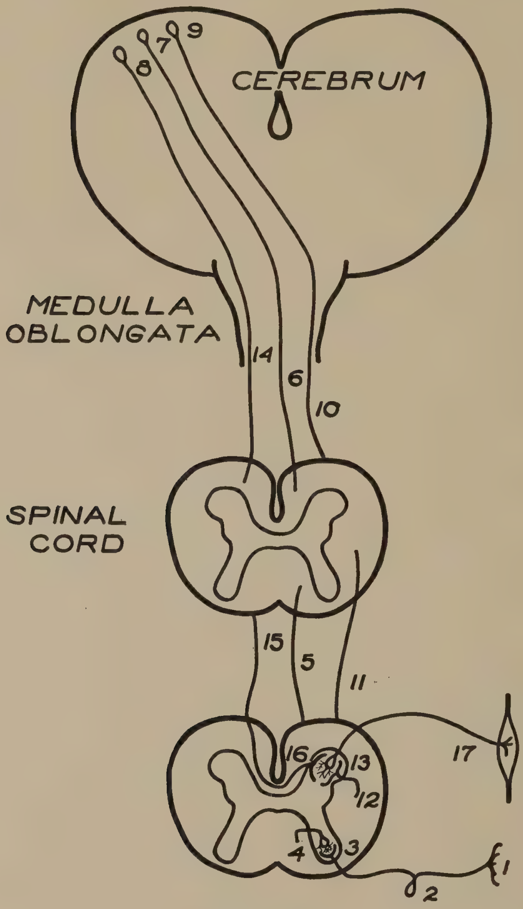

FIG. 102

indicate the same peripheral sensory neuron. At *3*, this forms synaptic connection with still another spinal sensory neuron. The axon of this neuron turns at right angles in its position in the white matter of the spinal cord (*4*) and runs directly upward on the same side of the spinal cord (*5*). When this axon reaches the level of the medulla, it crosses to the other side, proceeds upward through the internal cerebral structures and eventually ends in the cerebral cortex at the other side. When the nerve energy reaches the cortex, then and only then is one conscious of the stimulation of the sense organ which forms the dendrites of the peripheral sensory neuron.

The axon of the spinal sensory neuron makes synaptic connection with two spinal motor neurons whose cell bodies are in the cerebral cortex at 8 and 9. The axons of these two types of motor neurons both descend down the spinal cord and both eventually cross over to the opposite side of the body, but their course is different. The axon of cell body *9* comes to the level of the medulla, crosses over (*10*) to the opposite side and comes down the spinal cord in the position in the white matter indicated (*11*). When it reaches the lower spinal level, it turns at right angles and at 13, forms synaptic connection with the peripheral motor neuron already discussed under reflex and instinct. This is a fiber in what is known as the crossed pyramidal tract because it decussates or crosses to the other side of the body at the level of the so-called pyramids of the medulla.

The axon of the other spinal motor neuron (*8*) comes down to the level of the pyramids of the medulla and continues downward on the same side of the spinal cord in the position in the white matter indicated (*15*). When it reaches the lower level of the spinal cord, it turns at right angles, and crossing to the opposite side of the cord, forms synaptic connection with the same peripheral motor neuron at *16*. The axon of this peripheral motor neuron goes to the muscles which contract when stimulated.

Let us consider that the dendrites of the peripheral sensory neuron are located in the patellar tendon and that the muscle is located in the thigh. This chart, then, indicates the neural mechanism involved in a volitional kick of the leg when a subject is instructed to move his leg when he feels a slight touch on the patellar tendon. The ends of the arc, both sensory and motor, are exactly the same as those involved in the simple reflex. But now, because consciousness is involved before reaction, it is necessary for the nerve energy to go all of the way up to the level of the cortex of the brain and then all of the way down again through either the direct or crossed pyramidal tracts. The point of transfer between the sensory and motor ends of the volitional neural arc is to be found in the cortex of the brain. In a previous chapter we have indicated how complicated the cortical connection may be.

It is now appropriate to discuss briefly the problem of fatigue. It has already been noted that it is possible to demonstrate a reflex reaction after a muscle could no longer be voluntarily contracted. Fatigue is primarily but not exclusively a phenomenon of volitional reaction. Fatigue may mean any one of three things: (1) a decrease in the ability to do muscular work; (2) the accumulation of certain poisons and waste products in muscle and in the blood stream and (3) a conscious feeling of fatigue. It is the first of these three problems with which we are primarily concerned at the present time.

With an instrument known as the *ergograph*, a small group of muscles of a subject are isolated, so that they may be contracted alone. We may use the muscles of the finger or of the arm. The subject is instructed to contract these muscles in a definite rhythm, lifting a weight so that work will be accomplished. Such contractions always result eventually in a loss of efficiency. An example of two types of fatigue curves is given in figure 103. In both of these each stroke indicates a single contraction of the particular muscle group. The two records are quite different in form, however. In record A, it will be noted that these strokes become gradually shorter after the first several contractions and that the height of the strokes gradually diminishes until the weight cannot be lifted at all. On the contrary, in record B, the original degree of efficiency is maintained to the very end until finally the subject collapses altogether and can no longer move the weight. It has been found that one of these two types of fatigue curve is characteristic of an individual irrespective of the amount of work done or the particular muscle group which is being voluntarily contracted. If the weights are heavy or light and if the reactions are of the arm, the finger, leg or hand, one individual will always give a record of type A and another individual always a record of type B.

These individual differences in the form of the fatigue curve seem to indicate that there is some sort of a central factor involved and that what we have called muscular fatigue is not wholly a matter of muscle or of the accumulation of fatigue waste products. There is certainly involved some sort of fatigue of a mental sort. What relationship, if any, there may be between these fatigue types and the feelings of fatigue is not quite clear at the present time. There is not space here to discuss many important problems such as the relation of the rate of fatigue to the length and arrangement of rest periods and the like. Such problems are of primary importance in the application of psychology to industrial problems.

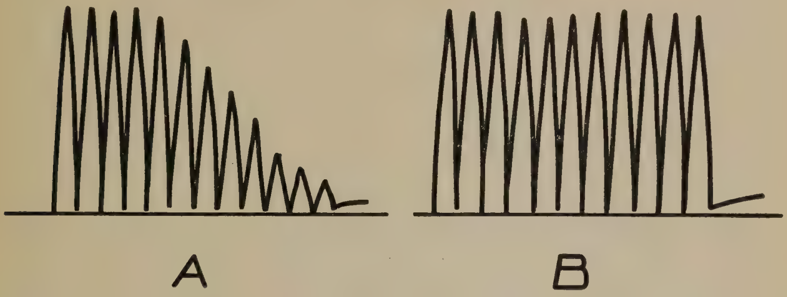

Fig. 103

In summary, then, the problem of volition has been discussed on the basis of a psychological definition, namely, that a volitional reaction is one requiring stimulation of the nervous system, in which the temporal order is stimulation followed by consciousness leading finally to reaction. On this basis, it has been found possible to explain volitional reactions, either singly or multiply determined, without appeal to any mystical concept such as a "will" which could spontaneously initiate reaction or which could determine which of several alternative reactions would become effective without reference to past experience or to present stimulation. From this psychological point of view, hypnosis and other forms of suggestion become typical examples of volitional reaction because for them consciousness precedes the reaction. A neural mechanism, involving the cerebral cortex and consciousness with known pathways up and down the spinal cord adequately accounts for these volitional reactions.

QUESTIONS

1. How is volitional behavior distinguished from reflex and instinct?
2. What is meant by suggestion?
3. What is meant by ideo-motor force?
4. How is the theory of hysteria related to volition?
5. What is the significance of post-hypnotic suggestion?
6. How are hypnosis and suggestion related to volitional behavior?
7. Distinguish between singly and multiply determined volition.
8. What three problems are involved in the study of fatigue?
9. On what grounds do we suppose a central factor to be operative in fatigue?

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Chapter XIX

HABIT

The reader would probably be willing to accept the challenge that he could not open his vest and button it up again within the period of one minute. If he tried this performance, he would find that he could probably unbutton and rebutton his best in something under 20 seconds. But in all probability he would still lose the wager. The challenge was that he open his vest and button it *up* again within the time limit. About four out of every five men button their vest downward and not upward. It is doubtful if many individuals realize in which direction they button their vests. This is an example of *habit.*

Nor will many persons be able to analyze, without first trying it, the intricate reactions necessary for buttoning a single button. When the opportunity offers, observe the reactions of a young child who has just learned to button his clothes. One will observe that this reaction is performed with close conscious direction. Consciousness *precedes* the reaction in these early stages of learning. At the beginning, this manual process is a volitional reaction. First the button hole is spread with the fingers of one hand and the button is grasped with the fingers of the other hand. The button is then inserted in the button hole and pushed half way through. The cloth surrounding the button hole is dropped and the button seized with this hand. The button is then pulled by one hand and pushed with the other until it is entirely through the button hole. You will discover that you still make exactly these reactions when you button your coat using two hands.

This reaction has its origin in a set of muscular movements which are consciously directed. As the result of practice and repetition, the amount of directive consciousness became less and less until, as in the case of buttoning one's coat, one may no longer be conscious that one has reacted. Habit, then, starts as volitional reaction and, as the result of practice, the degree of directive consciousness becomes less and less until it drops out entirely. The consciousness may drop out so completely that one may not even be aware of the fact that he has reacted in this habitual way. The temporal order of events for habit is thus stimulation followed immediately by reaction and this in turn sometimes at least followed by consciousness.

This temporal order in which the reaction precedes the consciousness and immediately follows stimulation is identical with that given for reflex and instinct. How then may we differentiate between these two sorts of reactions? Consider this example. Some years ago the author spent some time training a chimpanzee. After a time this animal would give an amusing response to stimulation. She would be told to dance and then one would clap his hands rhythmically. After a few claps of the hands, the chimpanzee would begin to leap up and down in a characteristic "dance." Was this reaction an example of habit or was it a reaction at the reflex-instinctive level? The setting of the problem has been purposely misleading to indicate that it was habit. This "dancing" is actually a reaction of the reflex-instinctive sort. It turns out that any totally untrained chimpanzee will leap up and down if stimulated by a rhythmic noise such as clapping the hands or pounding on a table.

Thus it is not possible to tell whether a given reaction is reflex or habitual unless one knows the normal instinctive reactions of the species and also the life history of the training of the individual animal. Reflex and instinct are based upon the stimulation of certain pathways in the nervous system which are present at birth. Habit is a reaction following the stimulation of certain pathways in the nervous system which have been formed during the lifetime of the individual and as the result of his own individual past experience.

Hence the pathways for reflex and instinct may be considered as *phylogenetic* in origin—that is, dependent upon the possession of neural pathways which are the result of natural maturation and growth. These pathways, and the reactions resulting from their stimulation, will be approximately the same for all members of the same species of animals. On the other hand, the pathways for habit must be considered as of *ontogenetic* origin. The pathways involved here are dependent upon the experience of the individual during his life time, and are built up by the particular past experiences of the individual.

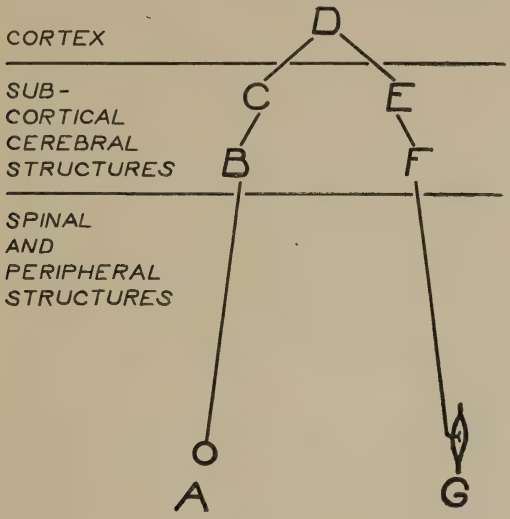
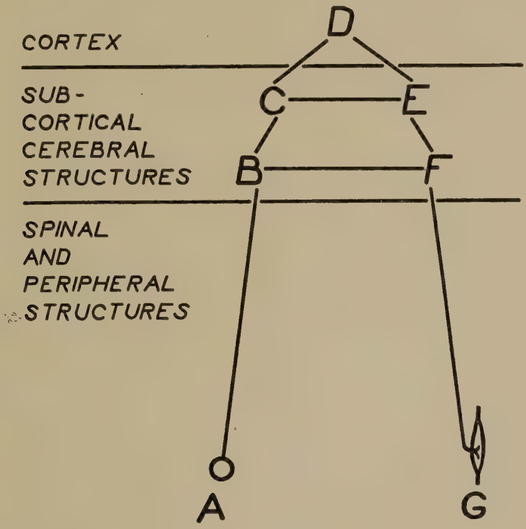

CORTEX
SUB-CORTICAL CEREBRAL STRUCTURES
SPINAL AND PERIPHERAL STRUCTURES
D
C
E
B
F
A
G

Fig. 104

There have been two points of view toward the development of these pathways for habit. In figure 104 a schematic neural pathway is indicated. Three neural levels are indicated: the cortex, subcortical structures of the cerebrum and below these the spinal and peripheral structures. *A* represents an end organ and *G*, at the other end of this reactive arc, represents an effector or reacting mechanism. Stimulation of the sensory end of this arc would mean that nerve energy would pass through all of the levels from *A* to *G*. As the nerve energy passed through the cortex there would be consciousness at *D* before the reaction of the muscle at *G*. This neural mechanism would be that representing the first stage—the volitional stage—before learning and before the development of the habit.

The first point of view regarding the neural mechanism for habit would insist that the neural pathway remains unchanged. Adherents of this view would say that the pathway for the most highly habitual reaction is identical with that when the movement was first made voluntarily under a high degree of conscious direction. They would say that all of the synaptic connections (at *B*, *C*, *D*, *E* and *F*) have become much stronger. This increase in the strength of the synaptic connections facilitates the passage of nerve energy from one neuron to the next. They would insist that consciousness occurs *only* when there is difficulty in nerve energy getting across a cortical synaptic connection. For these psychologists, the formation of habits consists merely in the development of a particular existing pathway in the nervous system through use so that nerve energy crosses the synaptic connections in this pathway more and more readily.

The second point of view would start as did the first. At the beginning, in the stage of volitional reaction, these psychologists would accept the schema of the neural pathways given above. A stimulation of the sense organ at *A* would lead to nerve energy passing through the pathway, involving consciousness at the cortex (*D*) and eventually leading to reaction. But the adherents of this second point of view would insist that new pathways are formed within the nervous system as the result of the repetition necessary for the establishment of a motor habit. These new pathways are indicated between *C* and *E* and between *B* and *F* in figure 105. These new pathways are conceived as occurring in the subcortical structures of the brain. They are conceived as being short-cuts so that the nerve energy no longer must pass through the cortex as a point of transfer from the sensory to the motor ends of the reactive arc. With the cortex eliminated in the new pathways, it will be recognized that directive consciousness is also eliminated after the habit has become established. Hence in the volitional stage before the development of the habit, the pathway was *A*, *B*, *C*, *D*, *E*, *F* and *G*. After training, with the development of the habit and the short cut pathways in the nervous system, the nerve energy travels only over the pathway *A*, *B*, *C*, *E*, *F* and *G* or even over *A*, *B*, *F* and *G*.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SUB-CORTICAL CEREBRAL STRUCTURES
SPINAL AND PERIPHERAL STRUCTURES
D
C
E
B
F
A
G

FIG. 105

There is some recent evidence that this second point of view of the formation of new pathways with points of transfer below the level of the cortex as the result of individual experience and practice is probably true. There is experimental evidence on animals who have been trained in particular motor habits. After the training was complete, sections of the cortex of the brain were removed. The animals were allowed to recover and it was found, in many cases, that there was no interference whatsoever with the performance of the habits already learned. These results would imply that those parts of the cortex were no longer a necessary link in the neural pathway between the sense organ and the effector. The elimination of this cortical link did not seem to affect the operation of the new pathway in which the point of transfer between the sensory and motor ends of the reaction arc must have been in the subcortical structures and so was not affected by the operation.

Observation indicates that the number of habits which an individual acquires during his lifetime is enormous. Which do you put on first, your right or your left shoe? Many readers will say that either shoe may go on first—it all depends on which shoe happens to be picked up first and this is a matter of chance. If you will observe your reactions for several days, it is very likely that you will find that you "happen" to pick up either the right or the left shoe first. Some years ago a student about to graduate applied for a position on the teaching staff of a small denominational college. The authorities sent him a questionnaire regarding his training, educational and religious backgrounds. This questionnaire ended with the following questions: "Do you smoke? Do you drink? Do you play cards? Have you any other habits good or bad?" In the meantime the student had obtained another position and so he tried to answer the last question perfectly honestly.

The result was a number of typewritten pages in single space enumerating this individual's personal habits. The President of the institution could have learned a lot about this individual from reading his summary of habits. He could have learned a very great deal about his personal daily reactions. Starting the day, one gets out of bed on a certain side even though both sides may be available. One holds the toothbrush in a particular hand—one brushes the upper (or the lower) teeth first. The right shoe (or the left) goes on first, and if it is the right shoe, one can be almost sure that the right stocking will also go on first. The enumeration of such personal habits may go on until finally and at the end of the day, one has certain habitual reactions in going to sleep. One may spend a few minutes lying on the left side of the body and then turn on the right side to actually settle down to sleep.

Some years ago a noted detective said that the average business man was the easiest person in the world to trail due to his large number of habits. Such a man leaves his house each day within a very narrow time bracket; he walks down his side of the street crossing at a particular place; he buys his newspaper at a particular stand; he goes into the subway by a particular stairs; he is either a front car, a middle car or a rear car rider and so on. Most of an individual's daily activity conforms to a particular habitual pattern week in and week out.

Indeed the larger number of habits which one can build up, the greater the efficiency of that individual provided these habits are good habits and useful habits. There is a great advantage in habit. Perhaps the development of habits makes the greatest contribution to human efficiency. The reason is that, once a habit has been developed, it will carry on with the highest efficiency, and thus release consciousness for control in other directions.

A noted man once said that he would never learn to drive an automobile because there were too many things to think about at the same time. If his statement had been true it is probable that no one would ever drive a car. But the statement is not true. After the habits have been formed, most of these reactions drop below the level of directive consciousness and one does not need to think about them. For example, construct what one does when he is held up by a traffic light and eventually gets his car into high gear. He must push down the clutch, throw the car into low, push down the accelerator and slowly let in the clutch. Then he must push out the clutch, throw into second, speed up the accelerator and let in the clutch. These reactions must be repeated again for going into high gear. In the meanwhile, he has been steering; noticing the car crowding on his left, smoking a cigarette and finally carrying on an animated conversation with the other person in the front seat with him.

One's directive consciousness has probably been wholly released to carry on the conversation in this case. All of the other activities, including puffing on the cigarette, have been carried on with the highest degree of efficiency below the level of conscious control. The real advantage of habit for human economy is that one is enabled to do two or more things simultaneously with as great efficiency as he was formerly able to do any one of them alone. These reactions which are entirely habitual will carry on with a normal degree of efficiency while consciousness is released to direct another activity simultaneously.

As a matter of fact, a habit once formed will be more efficient than an attempt to perform the same reaction under conscious direction. Try this simple experiment. Tie your necktie without looking in a mirror. Now tie your necktie slowly, explaining each step before hand to some one as if you were explaining this operation to one who did not know how to do it. You will find that you will do a better job—that the tie will be tied more efficiently and more correctly—in the first case than in the second where the explanation has furnished a high degree of conscious direction to a reaction normally at the habitual level.

Furthermore one may trust one's habits provided they are well established. How many individuals have had the experience of getting into bed and then wondering if they have locked the front door. One may get up and go down to the door and then one invariably finds that the door is locked. Like reflex, the habitual reaction is inevitable following stimulation provided the habit is well enough established.

One example of how the establishment of a habit releases consciousness for directing other activities is indicated in the learning curves of certain *complex* reactions such as the development of efficiency in typewriting.

Figure 106 represents a learning curve of increasing efficiency in typewriting. The curve is smoothed by the elimination of slight irregularities. The number of hours of practice are indicated on the abscissa. In this experiment 200 hours of practice were given. The efficiency is measured by the number of strokes of the typewriter keys in each 10 minute period. These efficiency records are erected as ordinates and the different points are joined to form the curve. Naturally the curve rises—practice increases the number of strokes in each unit of time. Hence the rise in the curve, as one goes from left to right, indicates an increase in efficiency with more and more practice.

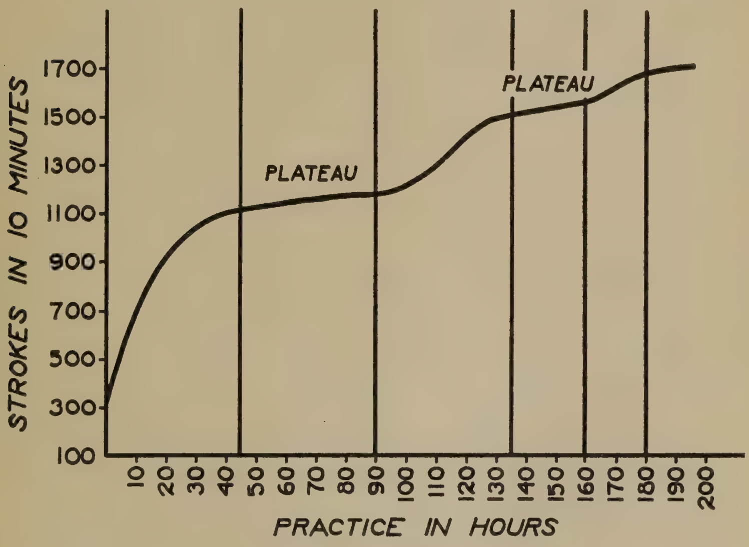

FIG. 106

But it will be noted that the increase in efficiency is by no means regular. At first the increase is very rapid indeed, and although the increase in efficiency is regular up to about the 45th hour of practice, it slows down considerably toward the end of that period. From the 45th to the 90th hour of practice there is very little improvement indeed. The curve runs along on practically a dead level during this period. This flat part of the curve has been called a *plateau.* Then there is again a sudden improvement as indicated by an increase in efficiency from the 90th to the 135th hour of practice. This second curve is very like the form of the initial learning, being relatively rapid at first and then gradually slowing down. Then there is a second plateau in which there is practically no improvement from the 135th to the 160th hours of practice. This plateau is again followed by a suddenly rising curve indicating improvement, similar in form to the former curves.

Learning curves of this type in which plateaus are present are found only for motor learning and only then if the habits are extremely complex. The acquirement of efficiency in such a complex activity as typing consists of several stages. In the first stage there is accomplished the association of a particular motor reaction with each particular letter. The first 45 hours of practice, in the curve represented above, mark the development of this first stage to its highest degree of efficiency. The second stage, from the 90th to the 135th hours of practice, indicates a period during which the typist learned to make a whole series of reactions for an entire word rather than a single reaction for each individual letter in that word. Thus such simple words as "the," "or," "and" were written as a *coördinated series of movements* rather than as single movements for each letter. Naturally greater efficiency is obtained during the development of this second stage. The third stage is one in which the typist learns such a series of coördinated movements for longer words and frequently for whole phrases

In the case of typing, then, one is dealing with the development of a *hierarchy of habits,* a situation in which the second stage of development is dependent upon the complete acquisition of the first stage. The typist cannot begin to acquire habits of a coördinated series of movements until each movement in the coördinated series has already become completely habitual. And the third stage cannot begin until the second stage has been completely habitualized. Each stage of development of the higher habits is dependent upon the accomplishment of the complete mastery of all of the lower ones.

Viewed from this point of view the plateaus become exceedingly important because it is during these periods that the lower habits are becoming entirely mechanized. Hence by the 45th hour of practice, the subject has reached his maximum efficiency at the first stage. During the period of the plateau of the next 45 hours, there is no increase in efficiency. But during this period these lower habits are becoming mechanized so that by the end of this plateau no directive consciousness is required any longer to maintain the final level of speed. Then and only then can the directive consciousness be released for the acquisition of the coördinated habits of the second stage of the hierarchy. Only when the initial habits can run along without any further conscious control can a still greater increase in efficiency be obtained.

The problem of the loss of motor habits presents certain curious anomalies at first glance. On the one hand, it seems that certain motor habits are retained after a very long period of disuse without any apparent loss in efficiency. Such activities as swimming and skating seem approximately as efficient after years of disuse as they were immediately after the learning period. You may not have ridden a bicycle for many years, but if you have ever ridden one, you may be sure that you could get on a bicycle today and ride with reasonable facility. Probably in these cases, where there is so little apparent forgetting, there was a very considerable amount of overlearning in the first place. Experimental results with human subjects indicate that if the motor habits are just learned, they will be lost at a rate not very different from the curve of forgetting for meaningful and nonsense material discussed before in connection with the topic of association. The loss of efficiency with time is rapid at first and then proceeds more and more slowly. Apparently there is little difference in the forgetting of mental material and the loss of motor habits. In both cases, permanent retention requires a very considerable degree of overlearning.

A habit, having once been established, seriously interferes with the development of other habits which may be antagonistic to or which may conflict with the first. Try this simple experiment. Take off your coat and put it on again noting which arm you put into its sleeve first. Now take off your coat again and put it on putting in the other arm first. You will probably find that this second reaction not only feels awkward but that it is much less efficient than your normal and habitual reaction. You have developed certain motor habits in your reaction to this stimulus situation and interference with these habits interfere with your efficiency. Try to tie a bow tie on someone else. Here all of your motor reactions which are habitual must be reversed in mirror fashion. Some individuals have so much difficulty in attempting to do this that they find it entirely impossible. To fasten such a tie on another person they must stand behind him, and reaching over his shoulders, use their ordinary normal motor habits.

How are habits once formed to be eliminated? It is obvious that, if the habit is well established by overlearning, it is useless to merely wait for its disappearance with disuse over a lapse of time. The elimination of a habit must be accomplished on a much more positive basis. To eliminate a habit it is necessary that it be brought back to the volitional level of conscious direction by some means or other. Bringing it back to the voluntary stage is the only way in which a habit already formed may be eliminated or another habit substituted for it.

This principle has been employed in the breaking up of such bad habits as biting one's finger nails. In the first place it is necessary to have the desire to break the habit. If this incentive is present, then the person should actively bite his nails for a certain time every day, but during this period, he must be completely aware that he is doing it as well as aware that he wants to eliminate the habit. The difficulty is that normally reactions of this kind are so well established that one is not even conscious that the reaction is taking place. One is not usually aware of the fact that he is biting his nails. Only when there is again conscious control can the habitual reaction be eliminated. Consciousness must again precede the reaction in the temporal order.

Let us summarize what has been said about reaction. There have been described four kinds of reaction—reflex, instinct, volition and habit. Instinct and reflex differ only in regard to complexity. *Reflex* is the reaction of only a part of the organism while *instinct* is the reaction of the organism as a whole. Both result from the stimulation of pathways present in the nervous system at birth. The origin of these pathways is phylogenetic. In neither reflex nor instinct does any consciousness precede the reaction. For reflex sometimes and for instinct always there is a subsequent consciousness—a conscious back-stroke that one has reacted or that one is reacting. *Habit* resembles instinct and reflex in that it is an immediate reaction following stimulation of certain pathways in the nervous system with no consciousness preceding the reaction. A conscious back-stroke may or may not follow the habitual reaction depending upon how well established the reaction may be. The difference between reflex and instinct, on the one hand, and habit, on the other, is that the habitual reactions are due to the stimulation of neural pathways established ontogenetically or during the lifetime of the individual. They are a result of individual experience. *Volition* differs from reflex, instinct and habit, inasmuch as, in this type of reaction, consciousness precedes the reaction and the consciousness seems to have some sort of a directive function and determines what the reaction will be. But again in volition there is required a stimulation of certain pathways in the nervous system as the first term in the temporal sequence. In none of the four types of behavior is the reaction ever spontaneous.

Figure 107 is an attempt to symbolize the relations between the four types of reaction. The essential figure is a spiral upon which are indicated the positions of reflex, instinct, volition and habit. The spiral shape brings reflex opposite to habit and thus emphasizes the fact that the two cannot be differentiated unless one knows whether the neural pathways are of phylogenetic or of ontogenetic origin. But the figure is a spiral and not a circle. A circle might imply, which is certainly not true, that a habit developed during the lifetime of one

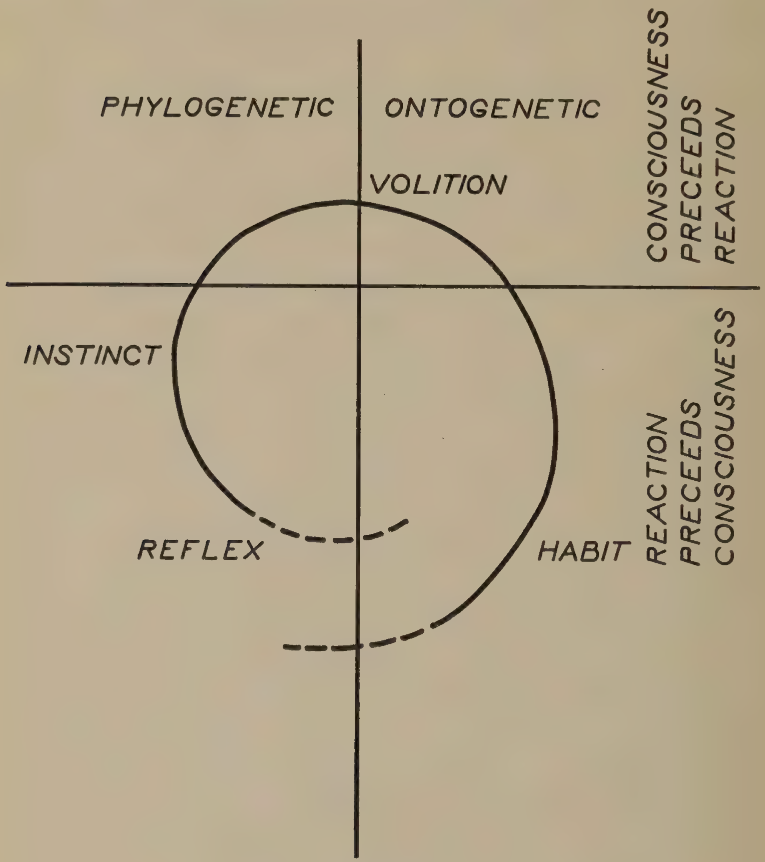
PHYLOGENETIC
ONTOGENETIC
VOLITION
CONSCIOUSNESS PRECEEDS REACTION
INSTINCT
REFLEX
HABIT
REACTION PRECEEDS CONSCIOUSNESS

Fig. 107

generation might be a reflex in the next generation. We know this cannot be true because the biologists have shown that acquired characteristics are not inherited.

This spiral is intersected by two lines at right angles to one another. The horizontal line divides the upper from the lower parts of the spiral. Below this horizontal line all reactions precede consciousness. On these parts of the spiral have been placed reflex and instinct, on one side and habit, on the other. Both ends of the spiral are dotted to indicate that even the conscious backstroke may be absent for certain reflexes and habits. As one proceeds upward from reflex through instinct, the conscious backstroke follows more and more closely the reaction. At the horizontal line we may conceive of a situation in which the reaction and consciousness are simultaneous. Above this horizontal line consciousness precedes all reactions and hence all such processes are volitional as that term has been defined in the present text. But a volitional reaction, often repeated, requires less and less directive consciousness. Thus, as one continues downward on the right side of the spiral, one again reaches the horizontal line at which place reaction and consciousness are simultaneous. Below this line is habit, in which reaction again precedes consciousness until, with great practice, even the conscious backstroke may be lost.

The spiral is also divided by a vertical line. To the left of this line all reactions have their basis in the stimulation of neural pathways which have a phylogenetic origin (reflex and instinct). To the right of this line, the pathways in the nervous system underlying reaction have an ontogenetic origin.

The *neural pathways* involved in these four types of reaction are schematically indicated in figure 108. This figure is divided horizontally into three parts. The lower part represents the spinal cord and the peripheral nerve connections. The middle part represents the subcortical structures of the brain and the highest part represents the cerebral cortex. In this figure *A* is a sense organ and *B* is an effector (as are also *F*, *G* and *H*).

In the case of all four reactions, the same sense organ (A) may be stimulated. In all four reactions the effector (B) reacts following the stimulation of sense organ A. Both the sensory and the effector ends of the four arcs may thus be considered as *final common paths* because the same sense organ and the same effector and the peripheral nerves of each are concerned in all of the reactions. Neurologically the differentiation between the four reaction types is to be described in terms of the neural pathways connecting the sensory and motor final common paths and in the position or positions of the points of transfer between the sensory and motor ends of the different arcs.

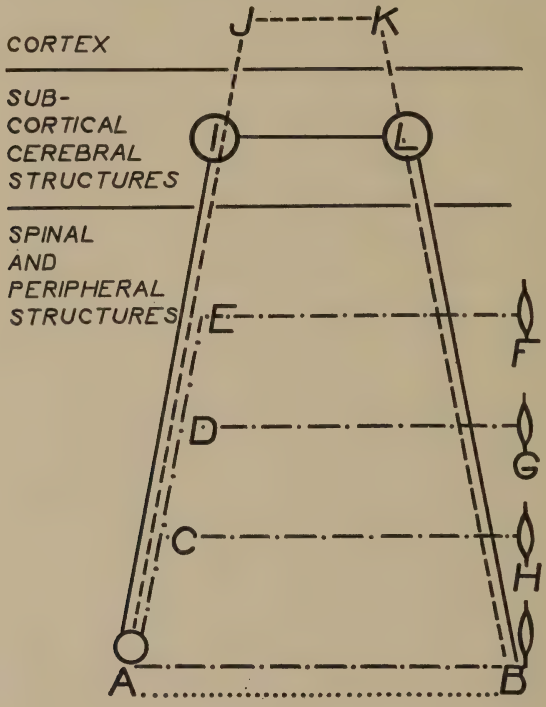

FIG. 108

The neural pathway for *reflex* is the direct dotted line between *A* and *B*. A single level of the spinal cord is alone concerned, and in this single level one finds the point of transfer between the sensory and motor ends of the arc. The pathways for *instinct* are designated by the dot-dash line. Here several levels of the spinal cord are involved. Nerve energy, following a stimulation at *A*, may go directly to *B* as before. But also some of this nerve energy may go to *C*, *D* and *E* and thus respectively stimulate effectors *H*, *G* and *F*. Transfer between the sensory and motor elements of these arcs involves several levels of the spinal cord.

For *volition*, designated by the dashed line, a stimulation at *A* means that nerve energy will pass up the spinal cord, through the lower brain structures to the cortex and down again to the effector *B*. Thus the pathway for volition is *A*, *I*, *J*, *K*, *L* and *B*. The point of transfer for volition, between the sensory and motor ends of the arc, is found in the cortex. Because of this, consciousness precedes reaction because nerve energy reaches *J* (a sensory center in the cortex) before it reaches *B* (the effector). For *habit* the neural pathway, indicated by the solid line, is *A*, *I*, *L* and *B*. Because of frequent repetition of a volitional reaction, a short-cut pathway has been established at the sub-cortical levels of the brain so that it is no longer necessary for the nerve energy to travel all of the way up to the cortex and back again to the effector. Thus directive consciousness is eliminated in the case of habit.

QUESTIONS

1. Distinguish between instinct and habit.
2. What two neurological theories of habit have been proposed?
3. Of what significance are habit hierarchies for economical motor learning?
4. How is the forgetting of motor habits related to the forgetting of memorized material?
5. How can habits be broken?
6. How is consciousness related to reflex, instinct, volition and habit?
7. In what respects are the neural pathways involved in reflex, instinct, volition and habit, alike and different?

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PART V. THE INTEGRATED ORGANISM

CHAPTER XX

DRIVE AND MOTIVATION

The night before this chapter was started the author slept restlessly. He was troubled by recurrent dreams which had to do with the writing of the chapter. These dreams were clearer and much more meaningful than usual. Particularly just before waking, they were concerned with possible variants of the verbal form of the opening sentences. This observation presents a problem which is the concern of the present chapter. We are here interested in why one thinks consistently along the lines of some particular problem. We are interested in why a person expends great thought and time and effort preparing himself for and then putting himself through college. We are interested in why a lover modifies his whole behavior in order to induce a girl to marry him and we are interested in why the girl consistently may refuse. We are interested in why animals migrate in winter and summer and in why some humans exhibit exactly the same behavior. In other words, we are interested in why individuals think and react *consistently* and *consecutively* in certain ways.

Many psychologists use the terms motivation and drive more or less as synonyms. Nevertheless, a perfectly valid distinction may be made between them. *Drive* may be conceived as consisting of those factors which *start* an individual reacting or thinking along a particular sequence. *Motivation* may be conceived as the fact that the individual *maintains* and *sustains* this particular sequence of thought or reaction after it has been started. It will be seen, for human psychology, that there exist certain distinctions in basic and fundamental factors which may differentiate drive and motivation.

This problem of why an individual starts and maintains consecutive thought and reaction along a certain particular line has been explained in one way by a group composed of physicians and not psychologists. These physicians are interested in mental disease for which both drive and motivation are exceedingly important problems. The theory which they have developed has been called *psychoanalysis.* Although this theory is probably not so important as it was some years ago for either psychology or medicine, nevertheless it still has such wide acceptance, in one form or another, and so many of the terms and ideas have been adopted into the popular vocabulary, that a brief description is worthwhile in the present place. It will be seen that this theory is quite different from the point of view toward psychological problems which has been developed in the present text up to this time.

Psychoanalysis starts with the acceptance of the existence of a *sub-conscious mind.* In this sub-conscious mind are stored ideas. Nothing is ever forgotten. No experience which the organism has ever had is lost. The idea of that experience remains in the sub-conscious mind during the entire lifetime of the individual. The psychoanalytic literature is full of references not only to early memories, but also to experience of the organism before birth when the foetus was still being carried by the mother. What we call forgetting consists merely in the inability of an idea in the sub-conscious mind to get up into consciousness.

One difficulty which an idea experiences in getting from the sub-conscious into the conscious mind is that it must pass what has been called the *censor.* This censor allows acceptable ideas to pass by into consciousness. But no unacceptable ideas are allowed to come into consciousness. They are repressed when they try to get by the censor into consciousness and are pushed back into the sub-conscious. Just why particular ideas are repressed depends on the particular psychoanalyst who is writing. One will say that they are ideas which have a sexual connotation of a sort that would be socially unacceptable. Another would say that they are ideas which involve a feeling of one's own inferiority and that this is also accompanied by a desire for power. These latter have been conceived as the basis of an *inferiority complex.* But in every case, the repressed ideas have a bad emotional overlay and are the result of some emotional shock or *trauma* which the individual has had in connection with them.

These repressed ideas are conceived as being the basis of all mental disease, on the one hand, and of all human progress, on the other. The reason for this is that something happens to ideas when they are repressed into the sub-conscious. One can best explain this by analogy. An apple kept in a damp cellar from light and air eventually rots and the rot of a single apple in time spreads throughout the barrel of apples. If such apples were kept in an air tight container, gases would develop which might eventually explode the container. Similarly an idea kept repressed in the sub-conscious changes in some way and the change may effect many or all of the other ideas in the sub-conscious. In time these become a source of *psychic energy,* which the psychoanalysts have called *libido.* If there is an excess of psychic energy one of two things may happen.

The psychic energy may have no outlet, in which case, it increases and is the basis of mental disease. Or the pressure of the psychic energy may be reduced by being drawn off into other channels. It thus becomes both the drive and motivation for productive activity. For example, one psychoanalyst has written a whole book to disclose the repressed ideas which he believes were the basis of the artistic and scientific contributions of Leonardo da Vinci. This use of libido for productive activity has been called *sublimation.* Psychoanalysts declare that all of the development of civilization,—science, art, invention, language, religion, law and government—is merely expression of repressed ideas in a sublimated form.

The psychoanalysts go on to say that there are three situations in which the censor is drowsy and off his guard. Once in a while this happens in the normal waking life; it also happens frequently in sleep, and during hypnosis. Hence a study of such things as slips in speech or writing or of minor accidents in the normal waking life, of one's dreams during sleep; and of one's thoughts during the hypnotic trance will reveal just which ideas are repressed in any particular individual. Furthermore, most psychoanalysts would insist that there is no human entirely without repressions.

But the censor is never really completely off his guard. He is merely inattentive during these several sorts of situations and if a repressed idea tried to get by the censor in its own right, the censor would become immediately attentive and would again repress this unacceptable idea into the subconscious and refuse to allow it to come into consciousness. So, the repressed ideas must put on a masquerade costume—they must appear as some other acceptable idea—in order to fool the censor and slip by into consciousness even during sleep and hypnosis. Hence it is necessary for the psychoanalysts to interpret the ideas of dreams and the thoughts during the hypnotic trance in terms of what have been called the *mechanisms*. Our knowledge of the mechanisms are allegedly the result of the analysis of a large number of cases by means of which the analyst has learned to know in what other forms certain types of frequently repressed ideas often occur.

For example, in the writings of certain psychoanalysts there is discussed what has been called the *Oedipus complex*. Following the story of Oedipus in Greek mythology, this indicates a repressed illicit love and desire of a man for his own mother. Naturally this idea would be socially unacceptable and its presence in consciousness would be a great shock to the great majority of individuals, who would certainly deny its existence. This idea, therefore, instead of getting past the censor in its own right, comes up from the sub-conscious mind, for example, as an idea that one is having an argument with one's father.

Practically all dreams which contain an element of dislike for one's father would be interpreted by certain psychoanalysts as indicating the presence of an Oedipus complex. This is true, say the psychoanalysts, because in this case the father becomes the son's rival for the love of the mother.

Psychoanalysts claim to cure mental ills and to develop character and personality. This is accomplished by a technique which consists in having the patient describe dreams, in hypnotizing the patient, and in having him report minor everyday accidents such as overturning a glass of water or misspelling a word or forgetting the name of some individual. These ideas are then interpreted into their true meanings, by use of the mechanisms, so that their true meanings may be known by the patient. Once the patient knows the true meanings of these ideas they are no longer repressed and hence the pressure of the libido or psychic energy has been reduced and the condition caused by this pressure relieved.

One of the main points of divergence among different psychoanalysts has been in the choice of mechanisms by which different repressed ideas are to be interpreted. It has been indicated that one group interprets repressed ideas almost entirely in terms of sex repressions and frequently employs notions of abnormal sex. Another group interprets repressed ideas almost entirely in terms of feelings of inferiority and a will to power. Each group of psychoanalysts, with some exceptions, tends to explain repressed ideas in terms of only a single class of motives such as the sexual motives or the desire for power.

If such a procedure of narrowing all motives to a single class is desirable, perhaps the ultimate has been reached in a recent work of a member of the psychoanalytic group. He has found an experience which is a shock (and thus produces a trauma), which is highly emotional and which is absolutely universal. This is the shock of being born. Certainly this experience is universal—after all every human being has been born; and certainly this experience is a shock because it is the greatest environmental change which the individual experiences during his lifetime. Before birth the foetus in the uterus is in a liquid environment with a constant temperature in which it is fed by the blood of the mother and in which it does not even have to breathe. To change from this environment to the world as we know it must be a shock indeed, and besides the process of being born must be as painful for the infant as it is for the mother.

This author makes the trauma of birth the basis of all psychic energy and hence the cause of all mental disease. In a sublimated form, the repressed memory of this single universal experience is made the basis of all human development such as language, religion, art and invention and it is even made the basis for the emergence of man in the development of the animal series. Do you like to lie and relax in a warm bath? This is regarded as a sublimated form of a desire to return to the former uterine condition before birth. One is told that rooms were invented because they are an expression of the uterus in sublimated form and hence the entering of a room is a return to the mother. One is even told that the invention of the elevator is a sublimated expression of the tubes from the uterus to the outside world. And the almost universally described unpleasantness of coming down in an elevator represents a sublimated rebirth.

It seems rather surprising how widespread has been the acceptance of psychoanalytic explanation, in some one of its several forms, as a description of motivation and drive. In this explanation, psychic energy caused by repressed ideas in the sub-conscious mind is made the basis for setting off the organism and for causing the organism to think or react consecutively along a certain line. The result of this reaction or thought is considered as merely the expression of the suppressed ideas in sublimated form. It is also curious how many of the terms employed by the psychoanalysts have become current in popular speech and popular literature, without one's realizing their true psychoanalytic significance or meaning.

The concept of a sub-conscious mind, in which ideas are stored, has already been critized on the discussion of memory above. For the explanation of psychological processes, such an assumption seems to be unnecessary. Psychological processes of memory and thinking seem to be more readily explained in other ways particularly with reference to traces due to past experience remaining in the nervous system and especially with reference to the activity and modification of certain parts of the cerebral cortex. And the assumption of the existence of a sub-conscious mind has been made the basis of all psychoanalytic theories of many varieties and kinds. Equally telling is the criticism that there has been no real attempt on the part of the psychoanalysts to explain their various concepts in physiological terms. For example, no attempt at localization in the nervous system is given for either the sub-conscious mind or the censor. This is particularly curious when one considers that most of the psychoanalysts are men with a background of medical training, with its emphasis on anatomy and physiology, and with the usual rejection of any processes which cannot be explained in terms of these sciences. Furthermore, the psychoanalytic explanation of drive and motivation does not correspond to or fit in with any of the descriptions of other types of psychological processes, conscious or reactive.

The fact that the psychoanalysts point to the cure of cases of mental disease by the use of this method need not be considered conclusive evidence of the truth of the underlying therapeutic theory. In the discussion of suggestion under the topic of volition, it was pointed out that, in cases of hysteria, a cure could be effected if, on the one hand, the basis of the condition was purely imaginary and if, on the other hand, the patient could be convinced that a certain actual thing caused the condition and that the cause had been removed. It may be believed that many psychoanalytic cures are of individuals with a hysterical background, whose ills are purely imaginary ones for which there is no organic or physiological basis. If such a patient can be convinced that (1) his trouble is due to repressed ideas and (2) that now that the particular ideas have been interpreted and brought into consciousness they are no longer repressed, then a cure has been effected.

One other difficulty with most psychoanalytic theory as an explanation of drive and motivation is that the interpretations are much too narrow. Certainly one cannot believe that all motives have their basis in repressed ideas of sex or of inferiority or of the shock of being born. As an explanation of drive and motivation, the psychoanalytic theories have emphasized ideas as the chief motivating factors. One hastens to add that these ideas are ones each of which has a highly emotional meaning and an emotional over-lay of reaction.

Perhaps equally narrow are the explanations of the group of psychologists who have approached the problems of drive and motivation from studies of *animal reactions*. In order to study the reactions of animals in an experimental situation it is necessary to get the animal to do something and thus it is necessary to present an incentive to the animal to induce him to react. Hence the animal is placed in one compartment of the experimental apparatus and the incentive is placed in the other. Then the animal will try to get from where he is to where he wants to go and a problem such as a maze, may be placed between him and his objective. If one wishes to measure the strength of different incentives an electric grille across which the animal must pass, may be placed between the animal and the incentive. In doing this he receives an electric shock. The intensity of the shock may be varied so that one may learn the relative strength of incentives by determining the intensity of shock which the animal is willing to receive in order to reach the incentive stimulus.

By this method the effect of various incentives was determined for the white rat. Hunger, thirst, sex drive and maternal drive were employed in successive experiments. In the study of hunger and thirst as drives, the animal was, of course, deprived of food and water, respectively, before the experiment. The length of time of these deprivations was considered an index of the degree of hunger and thirst. For the sex drive, a female was placed in one compartment as incentive for the male in the other compartment. For the maternal drive, the newly born litter was separated from the mother, and used as incentive. In this set of experiments a study of the exploratory drive was also made, although this is more random in character than the others and is not so clearly directed toward a specific incentive. It happens that the white rat is an animal with a very curious nature; he will explore any object new to his experience. Hence the introduction of a novel stimulus itself gave incentive for this drive.

These five incentives have been considered as the bases for the normal drives of the white rat. All incentives were kept constant throughout the five experiments except the one studied at the moment. Thus all rats had the same degree of hunger for each experiment except in the case of the study of the hunger drive and so on. The results indicate that, under these conditions, the maternal drive is the strongest, that is, the animal is willing to receive a stronger shock in order to reach its young as incentive than for any of the other incentives. Then in rank order come thirst, hunger, sex and finally the exploratory drive.

These experiments are admirably conceived as a basis for the study of the relative adequacy of certain incentives as drive for these animals but they again give us only a narrow aspect of the motivation and drive problem because of the nature of the experimental material. One difficulty with the psychoanalytic approach, even if the underlying theory were true, is that it too strongly emphasizes the ideational and intellectual elements of the situation. The trouble with the experimental work on animals is that it so completely ignores just these ideational elements, and throws the emphasis upon instinctive reactions. Naturally this is true for any animal experiments, because it is so manifestly impossible to have an animal introspect upon and describe what is going on in its consciousness.

The problem of drive and motivation presents what is perhaps the most complex aspect of human psychology. No simple approach, such as the ideational emphasis of psychoanalysis or the instinctive approach of animal psychology, will give anything like an adequate picture of the complexities of human drive and human motivation. It is doubtful if a complete description of any particular experience for any particular human can be written. The experimental and introspective data for such a single description does not exist in the literature and probably it can never exist for any complicated situation. Certainly no formula can be written which will be a true description of any sort or type of sustained human activity toward a goal.

But in every case a stimulus must be present which impinges upon the nervous system. The perception of this stimulus is the *incentive* which sets off the drive. And the drive is thus always towards some perceived *goal.* This may be either toward the stimulus situation or away from the stimulus situation. The stimulus situation may be simple or it may be exceedingly complex. For example, consider the complexity of the incentives which may be operative in creating a drive toward obtaining an education in college.

In the first paragraph of this chapter a number of examples were indicated as falling within the problem of drive and motivation. It seems possible in a very general way, to indicate some of the great variety of factors which may be operative in each of them. But the reader is again warned that each of these examples is too complex for complete psychological description at the present time or possibly in the near or distant future. And the reader is warned that what might be a complete description for any individual in any one case might be entirely different from that of another individual for the same drive and the same motivation.

The first example had to do with consecutive thinking even as it occurred in dreams during sleep. Here both the incentive for the drive to set off this consistent thinking and the motivation which kept it going were largely an ideational affair. A complex idea was the incentive and this became a *goal idea* which determined the sequence of thinking in the period of waking or even during sleep. This type of problem has already been discussed as *intention* under the general topic of thinking, some chapters above. Here the frank admission was made that, at present, psychology cannot explain how a particular idea becomes a goal idea and thus has a directive influence on the sequence of subsequent ideas and of their organization. The belief was expressed that, in some way, the presence of the goal idea lowers the resistance of particular association pathways out of the much larger group of possible association pathways.

The second example had to do with the drive and motivation of preparing oneself for and putting one's self through college. It will be recognized that this is a case involving the persistence of consistent thought and reaction over a long period of time—in this case, over a period of a considerable number of years. In such a situation, the drive which sets the consistent series going is apt to be a combination of intellectual experiences which create goal ideas and also probably a series of emotional reactions. But in most cases, the incentives are more apt to be ideas than emotions. What these ideas or emotions, which act as incentives, may be in any particular instance will vary profoundly from case to case. The same tendency toward an intellectual basis for continued motivation would seem to be the primary factor in this long-time consistent exhibition of behavior and thought.

The third example is of the lover who wishes to marry a particular girl. Here the situation is quite different from the two examples discussed above. In this case the drive which starts the reaction toward the goal will be largely composed of a mixture of instinct and emotion with only more or less of an admixture of ideational contribution. The girl, as a stimulus, sets off a group of instinctive and emotional reactions which are intense enough and which are durative and prolonged enough to set up consistent behavior toward the goal. Once these reactions have started there will probably be a tendency for the longer continued motivation to have a much larger ideational contribution. But, in this case, the instinctive and emotional components will be much larger than in the two cases of thinking outlined above. Each time that the man sees or even thinks of the girl, some of the instinctive and emotional reactions will be revived. And the girl who consistently refuses him may differ from the lover who desires her in either of two ways. Either she has not had the instinctive and emotional reactions toward the man which might act as drive toward him as goal or, if they exist, she may have certain intellectual processes which act as goal ideas leading her in another direction and thus inhibiting the reactions which might have acted as incentive, drive and motivation.

The fourth example had to do with animal migration. From what we know of these reactions in birds and in other animals, both drive and the subsequent motivation are to be explained largely in terms of instinct and possibly emotion. It seems doubtful that there is any considerable ideational contribution in this situation. It seems incredible that a bird has any pictured goal idea in consciousness as it starts or as it continues to fly south in the autumn. And it seems incredible that the bird would have any clearly pictured conscious idea of the consequences of this flight. A gradual lowering of temperature and a possible increasing scarcity of food is the stimulus and the incentive for this reaction, and under conditions of continued stimulation, the animal keeps up the instinctive reaction until it reaches a region where the stimulus is no longer present and hence the incentive for continuing the reaction has been removed.

But man may migrate as well as animals. There are examples of seasonal migration of individuals year after year. Some individuals go south every winter and back north again in the spring with the same regularity exhibited by animals. Certain tribes in Persia migrate as a whole from one part of the country to another twice every year. In this migration, which is over a high mountain range, they experience great difficulties and extreme discomfort. The incentive in this case is to obtain pasture for their flock—the available pasture lands for summer and winter being in the valleys on different sides of the mountain range. The migration reaction is not essentially different for these humans than it is for animals and the reasons for these human migratory reactions are also similar to the animal incentives. But in the case of human migration, the elements are almost entirely ideational for both drive and motivation and hence differ from the instinctive bases for animal migration.

The brief and entirely inadequate analysis of these several examples merely indicates the complexity of human drive and motivation. It has been found that *instinct*, *emotion* and *ideas* may be components of the *drive* which starts an individual thinking or reacting consistently. It has also been found that these same components may be effective in the *motivation* which keeps the individual reacting and thinking in consecutive fashion. But what mixture and what proportions of which of these components may be present for any particular reaction is a matter for individual analysis and individual description. And the situation in human behavior is so complex that such analysis is, at the least, extremely difficult.

In this analysis one may indicate that there is apt to be a relatively greater admixture of instinct and emotion in drive and a relatively greater admixture of ideation in motivation. In other words, it is the complex immediate reaction to a stimulus without directive consciousness, such as is true in emotion and instinct, which frequently initiates human behavior in a given direction. It is frequently a clearly conscious goal idea which keeps human behavior moving in a given direction toward a particular end. But the few examples outlined above indicate that no formula can be written for any complex human reaction or any complex train of thought. It has been found that either instinct, emotion or idea, or any combination of them, may constitute either drive or motivation.

QUESTIONS

1. What is the psychoanalytic explanation of drive and motivation?
2. What is the function of the censor? of sublimation?
3. On what grounds may psychoanalytic doctrine be criticised and defended?
4. How is motivation studied in animals? How do the five incentives rank in order of strength in the case of the rat?
5. What explanation may be given to the migratory behavior of animals?

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CHAPTER XXI

INDIVIDUAL DIFFERENCES

Certainly no two people are exactly alike in every respect. It is equally true that no two people are exactly alike with respect to any particular characteristic—physically, physiologically or psychologically. Finger prints are an outstanding example of individual differences in the physical or anatomical realm. No two individuals have finger prints so similar that they cannot be differentiated as the result of careful study by experts. There is evidence that great *individual differences* exist in human anatomical characteristics. It can be said, without question, that much wider differences exist in regard to psychological characteristics.

If we should measure the heights of a large number of individuals, we would find a very few who were exceptionally short and a very few who were exceptionally tall but we should find that the large majority of individuals tended to group themselves about the middle or average value of heights. If our number of cases were large enough and we arranged the results into a curve of *frequency distribution,* it might appear like the one given in figure 109. This is a purely imaginary curve from which one may discuss certain theoretical implications. Along the horizontal base line or abscissa various heights are laid off at equal distances for the hypothetical units *1* to *9*. Along the vertical line or ordinate numbers of cases from *A* to *I* are laid off at equal distances. The curves are constructed by placing a dot opposite the observed number of cases directly above the point on the abscissa for each height. If *1* is the shortest and *9* is the tallest individuals measured it will be seen that the two ends or "tails" of the curve are low and that the number of cases "pile up" toward the middle values, with the greatest number of cases at the central value *5*. Such a curve has been called the *normal curve of distribution.* It is bell shaped and bilaterally symmetrical, that is, one-half of the curve is an exact mirrored reproduction of the other half. In such a curve, the highest frequency of occurrence, the central value and the average will all fall at the same place above the abscissa. These values have been called respectively the *mode*, the *median* and the *mean* or *average*. In the case of the example above all three of these values will be seen to fall at the height with a value of *5*.

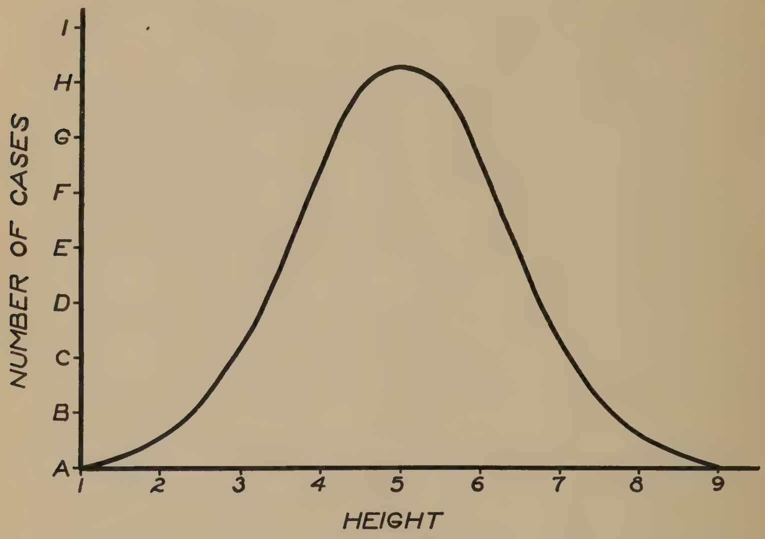

Fig. 109

If a series of measurements when plotted should give a curve such as this one, it has been pointed out that one may call this central value at which the median, average and mode coincide, the *typical value* for the particular characteristic which has been measured. In the present case, the typical height of this group is *5* units. Then all values above or greater than this will be considered superior and all cases below this central value will be considered inferior. The degree of inferiority or superiority, for any particular case is determined by the distance this score lies from the central value. Thus an individual whose score is *9* is very much more superior than one whose score is *6* or *7*.

Actually such entirely regular and smooth curves are seldom if ever obtained in actual practice. They could only be obtained if the number of cases measured should be extremely large and also if one was measuring only a single factor in isolation or a group of factors operating together to give a single composite result. Many years ago, an investigator measured the heights of a very large number of recruits for the French Army. When he plotted his results he obtained a curve in form like the one given in figure 110. This curve has two peaks or modes and it has been called a *bimodal curve.* An analysis of the results indicated that they were a function of a mixture of human types, in this case of the original Celtic types and the types introduced by the Roman and other Mediterranean invasions. Such a curve always indicates a *mixture*

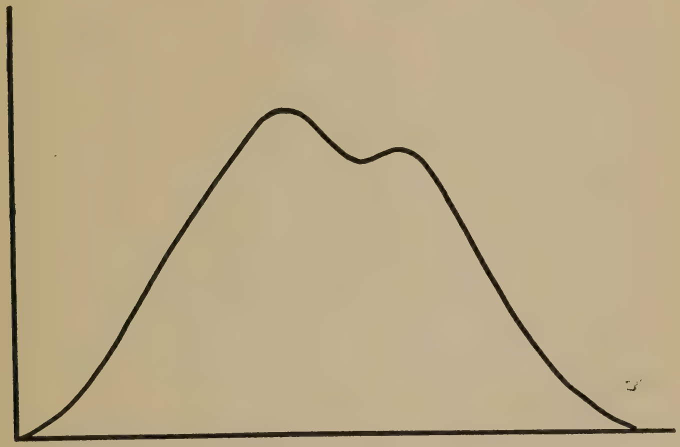

FIG. 110

of types and indicates the fact that one has not measured a single factor or a single group of factors always leading to a single result. There are examples of curves with three or even more modes.

Sometimes the differences in the two factors mixed together are not great enough to give actually separate modes or peaks. In that case, when one plots the results, he obtains a curve like the one given in figure 111. This curve is somewhat similar in form to the normal curve but it will be observed to be asymmetrical. There will be seen to be a tendency for a piling up of results toward the higher values in this case. This has been called a *skew curve.* In such a curve the mode, median and mean will not correspond and none of these values is apt to fall upon the central value of the scale of measurement.

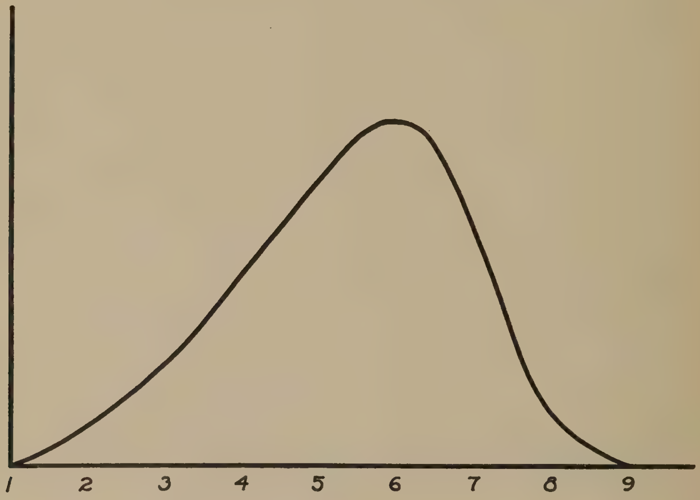

FIG. 111

Two curves of the distribution of an equal number of measurements may vary in the way indicated in figure 112 and both still be of the normal form. In both cases these are typical curves and in both cases the central or "typical" value is of identical magnitude. But one curve is high and concentrated about the central value and the other is flat and widely spread out. The low flat curve is said to have greater *scatter* than the high curve which indicates much greater individual variation within the group. Thus the low curve is seen to include many more very high and very low examples than the steeper curve.

Also two curves may be identical in form but may vary with regard to their position on the abscissa. Such curves are indicated in figure 113. These curves are identical in form but one is up at the higher abscissa values and the other is over the lower. Both are typical curves but the central value for the left hand one is at *3* and for the other curve at *7*. If these curves represented the measurements of psychological characteristic identical for two groups, one could say that both groups were typical as regards the characteristic but that one group had much more of it than the other.

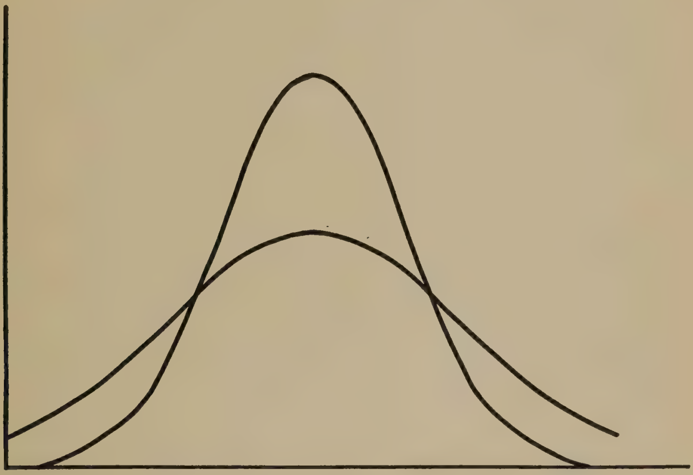

Fig. 112

So much for the general statistical background for considering the problem of individual differences. For further information, the reader is referred to any text on statistics which will develop the concepts here merely indicated. In the present text, we cannot give the space for a real development of the problem of individual psychological differences. This is a matter so important and of such magnitude that it must be treated in its own right. It is primarily the concern of clinical and of educational psychology. Nevertheless, an attempt will be made in the present place to indicate some few bases of individual differences and some of the consequences which may be inferred from these psychological differences between individuals.

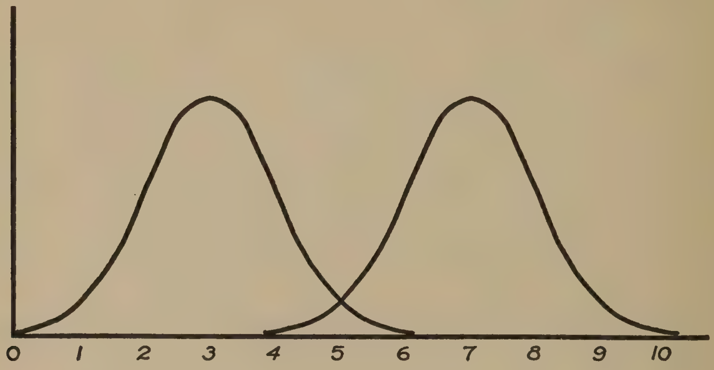

FIG. 113

The statement cannot be questioned that there are individual differences for every psychological characteristic or for any combination of such characteristics. For example, in such a simple and fundamental characteristic as color vision the range of ability runs from superior color vision, through normal color vision and on through all of the various degrees of color weakness and partial color blindness to total color blindness. Such a distribution of individual differences is to be found in any of the simpler psychological processes—either conscious or reactive. The curve in figure 114 gives the distribution of limens or threshold values for 70 individuals for the judging of small differences in lifted weights.

These are the results from 70 individuals taken under the same experimental conditions. In a particular rhythm they picked up first a standard weight of 100 grams, and then one of a series of comparison weights, immediately making a judgment as to whether the second weight was heavier, equal or lighter than the first. Many hundreds of such judgments were the materials from which a statistical *limen* or *threshold* could be calculated. In this case only the rough *polygon* of distribution is presented. The smooth curve for these values is not drawn. The threshold values will be found along the abscissa and the number of cases for each value is erected as an ordinate. Hence it will be seen that three individuals had a threshold of 2 grams. This means that these three individuals were able to report a 98 gram weight as lighter and a 102 gram weight as heavier than the 100 gram standard in 50 per cent of their judgments.

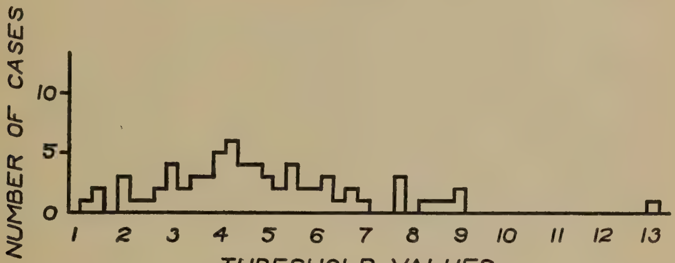

Fig. 114

It will be seen that the thresholds vary from 1 gram at the one extreme to a single isolated case of 13 grams at the other extreme. There is a general tendency for the cases to pile up about the middle value. The highest frequency (6 cases) is at 4.25 grams. This curve is based upon the results of only 70 individuals, all from a highly selected group of graduate students or advanced undergraduates majoring in psychology. The curve is not regular. The number of cases is too small to expect anything like complete regularity. But even if the number of cases should be very much increased, it is seldom if ever that one obtains complete regularity among the measures of any particular psychological ability.

The study of individual differences has led to the development of what have been called *mental tests.* A test is presumably a method of determining the degree or amount of a psychological ability present in any individual. The aim is to make this determination easily and rapidly. As a matter of fact, it is exceedingly doubtful if any test exists which will measure any single psychological ability or characteristic solely and in isolation. One approaches the ideal most closely in the measurement of sensory and perceptual capacities, such as the results for judging small differences in weight described above.

Contrasted to this are the so-called *intelligence tests* which presumably measure that very complex thing which has been called *intelligence.* Intelligence is best defined as the *ability to solve a problem new to the individual.* On the basis of this definition it may be asserted that animals possess a higher degree of intelligence than that for which they are usually given credit. Chimpanzees are able, for example, to solve the problem of reaching food hung too high for them to jump. They solve this problem by piling available boxes on top of one another and mounting this improvised ladder. Chimpanzees learn, without instruction, to use a stick to pull food within reach when it is too far from the bars of the cage to be grasped directly.

Perhaps the best method of measuring intelligence is by means of *performance tests.* Many of these consist of boards with holes cut into various geometrical shapes into which blocks of the different shapes must be placed. The speed and the correctness with which this is accomplished measure the degree of intelligence. These performance tests vary from exceedingly simple ones, for which each block is exactly the shape of a hole in the board, to very complex ones indeed. In the latter, the blocks for each geometrical form are cut into several pieces and the subject must sort out the pieces which belong together. It has been found that intelligence, as measured by such performance tests, varies from correct completion in a very short time without error to complete failure to finish the task in any length of time.

There exist a great many "paper and pencil tests" which are usually called tests of intelligence. These consist of batteries of many different kinds of tests, involving such things as memory span, the understanding of words, the solution of reasoning problems and the performance of arithmetic. Some of the individual tests which form some of these batteries may be tests of intelligence. The solution of most of them requires a specific background of knowledge for its accomplishment, and therefore, they are really tests of intellect rather than tests of intelligence. They are this because *intellect* is based upon the acquisition due to one's own past experience. Such batteries of tests have been devised so that the results may be obtained simultaneously from many hundreds of individuals. Tests like these obviously measure a very great complex group of psychological abilities and characteristics rather than single ones in isolation.

During the World War a series of such tests were developed for the United States Army. They were given to nearly a million and three-quarters of men in the draft. The scores on this test ranged from the highest possible of 212 points to zero. Letter rating was given, the ranges of scores as follows:

A	Very superior	135–212
B	Superior	105–134
C	High Average	75–104
C	Average	45–74
C–	Low Average	25–44
D	Inferior	15–24
D–	Very inferior	0–14

The results of scores in this test of over 94,000 men of the white draft fell into the distribution shown in figure 115. The curve represents the percentage of individuals who fell within the seven classes. It will be observed that there is a large piling up of cases toward the central values. This polygon indicates a very wide distribution of abilities necessary for the solving of this battery of tests. The curve is skewed toward the higher values on the left hand side.

When the same tests were given to nearly 5,000 college men and women, representing a much more homogeneous group than the white draft, a wide variation in individual scores was again to be noticed as will be seen in the curve of distribution given in figure 116. This curve is quite similar in form to that for the white draft given above. It is skewed toward the lower scores to the right, although the amount of skew is not as great for the college students. And there is a considerably greater percentage of high scores for the college group. This is exactly what one would expect inasmuch as the college curve represents the results of a much more highly selected group than the white draft,—both with regards to intelligence and intellect.

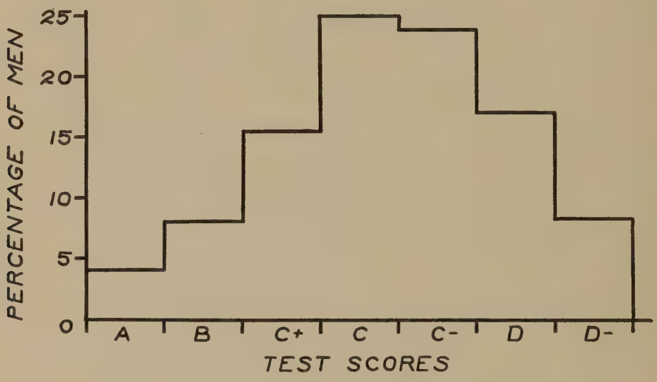

FIG. 115

In order to show how different the results for the college group and the white draft are, the results have been reduced to percentages, and the two curves are reproduced together in figure 117. Both curves indicate the percentage of cases which fall within the seven different letter groups. The solid curve is for the white draft and corresponds exactly to the one reproduced above. The curve for the college group is represented with a broken line. A glance at these curves indicates their marked difference. Although the college curve, by scores, gives results somewhat approximating the typical form; when the results are thrown into the percentage form, there is a tremendous piling up of cases toward the higher test score values on the left. It will be observed that in the college group no cases are recorded for the categories D and D–.

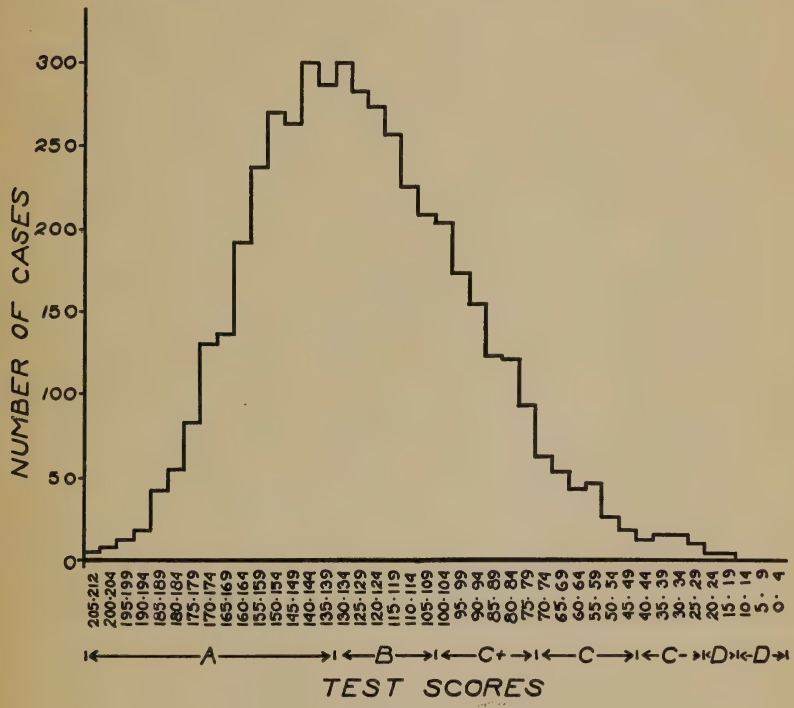

Fig. 116

From these observations it is perfectly evident that it is possible to arrange a large number of individuals in rank order with regard to such psychological characteristics as intelligence and intellect even though it must be realized that both of these are psychologically exceedingly complex. If this should be done for all of the individuals in the world, the curve would undoubtedly be of the typical form—low at both ends and high in the middle. At the end of the lowest scores, we should find the *idiots*, and proceeding onward we should pass through the low normal, the *normal*, the high normal, the *superior* and finally, at the extreme other end, the group which might be called *genius*. Such a distribution, in terms of individual differences in test scores, not only gives a definition of normal

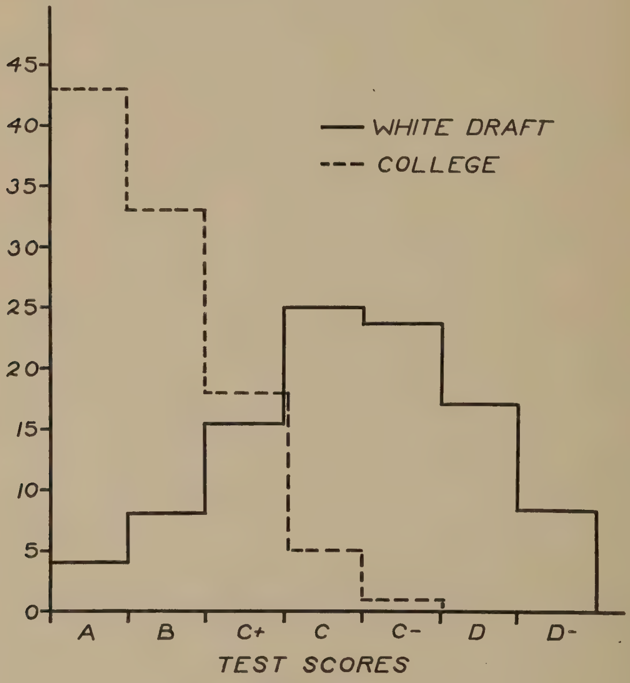

FIG. 117

but also defines, in part, the two extremes of individual variation.

But test scores alone will only define such extremes as idiocy and genius in part. Another part of the definition depends upon the social environment in which the individual finds himself. An individual may have a degree of intelligence which is insufficient to permit him to compete in the complicated environment of a big city. But this same individual might not be considered feebleminded at all in the environment of an isolated rural community. There exist many such small isolated communities where all of the residents eke out a living, but in which a very large proportion of the population would be considered feebleminded in a large urban community.

It has been found that individual differences in the degree of intelligence aid in the formulation of our definition of individual differences such as feeblemindedness and genius. And it must be emphasized that those individuals at the genius end of the scale are as far removed from the central normal group as are the feebleminded at the other end. From this point of view, both the feebleminded and the genius are abnormal individuals.

Let us see if this sort of treatment of individual differences for another sort of psychological characteristic will aid in the formulation of other definitions and thus lead to a better understanding of the concepts which they represent. Consider the question of *intention, drive* and *motivation.* At one end of the scale we would place individuals who were unable to maintain sufficient motivation even to complete the thought of a single short sentence. Each sentence might begin with one idea and end with some totally unrelated idea. This is characteristic of a certain kind of *insanity* and there are many such cases in our institutions for the insane. From this extreme one would pass through cases of individuals who were extremely vacillating and who were unable to maintain a constand motivation over any considerable period of time. Then would come the "*flighty*" individuals who rave about bridge one week and about crossword puzzles the next—people who never stick at any one thing for any length of time. And so we might go on through examples of normal motivation, through determined individuals who maintain a constant motivation in spite of difficulties and finally, at the other end of the scale, to those individuals with such strong single motivation that their condition may be described as a *fixed idea.*

This other extreme is also abnormal and such constant and single motivation as that which can be described as fixed idea is characteristic of another form of insanity. This condition may be the basis of *delusions* in which the individual may build up for himself a mental world which does not correspond with the actual physical world in which he lives. The "Napoleons" and "Messiahs" to be found in our institutions for the insane are characteristic of this condition. In these cases the fixed idea has led to the building up of an unreal world which is so complete that it has entirely modified the thoughts and reactions of the individual.

Thus it would seem that a study of individual differences of such a psychological characteristic as the degree of constancy of motivation may greatly aid in our definitions of insanity. Both extremes are again seen to be abnormal. Both extremes represent different kinds of insanity. At present, there is no adequate series of tests for making a quantitative determination of this motivation characteristic. But even if such tests existed, the score *alone* would not be sufficient for the determination of whether a given individual could be considered normal or insane. As in the cases of genius and feeblemindedness, there must be a certain social aspect to the definition of insanity as well. To be judged insane, one must not only be at one or the other end of the motivation scale, but one must also have brought abnormal reactions or ideas which have, or are apt to bring the individual into conflict with society. There are many people walking the streets today who are more insane than some of the inmates of our asylums. One might have a fixed idea that he must never step on a crack in the pavement and he may walk the streets for many years with this persistent idea completely modifying his behavior. Still he would never come in conflict with society. But if his fixed idea should take the form of believing that someone was trying to throw poison powders through his window, he would soon find himself in trouble. With this particular delusion, he would be in conflict with society. He might become a murderer if his delusion became fixed upon some other particular individual.

It has been seen how individuals within a group may differ from one another with regard to a single relatively simple characteristic, such as the ability to judge small differences in weights or with regard to such complex combinations of psychological processes as intelligence, intellect and motivation. The comparison of the test scores for the white draft and college adults of the Army tests indicates a method by which one group may be compared with another with regard to any characteristic or combination of characteristics. Many such comparisons appear in the psychological literature.

For example, the problem of *sex differences* has interested a great many psychologists. Comparisons, which have been made for many different kinds of psychological abilities indicate much greater similarities than differences between the two sexes. With few exceptions the average results are almost identical for the psychological abilities which have been measured. On the whole the results for the females will be more homogeneously clustered about the central values than those for the males. Thus the curve of male scores will frequently be of much wider spread than that for females, indicating greater male individual variability. There will be more males exhibiting highly superior but also more cases of males showing greatly inferior ability of the characteristic measured. Results show that boys show a real superiority over girls in tests requiring skill in manual coördination such as the performance tests mentioned above or tests of mechanical ability. Such differences in scores, in these particular traits, can probably be completely accounted for in terms of the different backgrounds of past experiences of the two sexes. Certainly in the past and probably still today, boys have much more practice in mechanical things than girls.

There have been many studies of *racial differences* especially of white and negro children. The results are fairly clear cut although their interpretation is not nearly so obvious. The score for most so-called "intelligence" tests indicate a superiority for the white group. Curves of the distribution of scores for a negro and a white group, matched for age and school grade, show a great deal of overlapping, but the whole curve for the white group would be pushed somewhat toward the higher score values. If these results were taken at their face value, this would indicate a superior intelligence for the white group. But it has already been pointed out that these tests measure intellect rather than intelligence—they measure more what the individual has acquired than what he would be able to acquire. And there can be little doubt that the average negro, in this country, does not have as great social, economic and educational opportunities as the average white. In all probability, the group differences which have been demonstrated between these two races are to be accounted for by these underlying differences of opportunity for intellectual development rather than by any underlying differences in fundamental intelligence.

Until now we have spoken only of differences between individuals or groups of individuals with regard to one or another of the simple psychological abilities or groups of abilities. One exceedingly important problem has to do with the *changes which occur in the individual himself at different periods of his life.* This question of *ontogenetic development* is of obvious importance especially for educational psychology. The results are numerous and cover measurements of the development of a very large number of human psychological activities both conscious and reactive. For example, the curves given in figure 118 indicate a steady improvement for both the right and left hands between the ages of 6 and 18 years for the simple reaction of tapping as rapidly as possible. These values are derived from averages of a large number of cases at each age. It will be seen that the curves for the two hands remain almost parallel, with the right hand invariably giving the better performance at all ages. By the end of this period of 12 years, the number of taps with either hand is almost double what it was at the beginning.

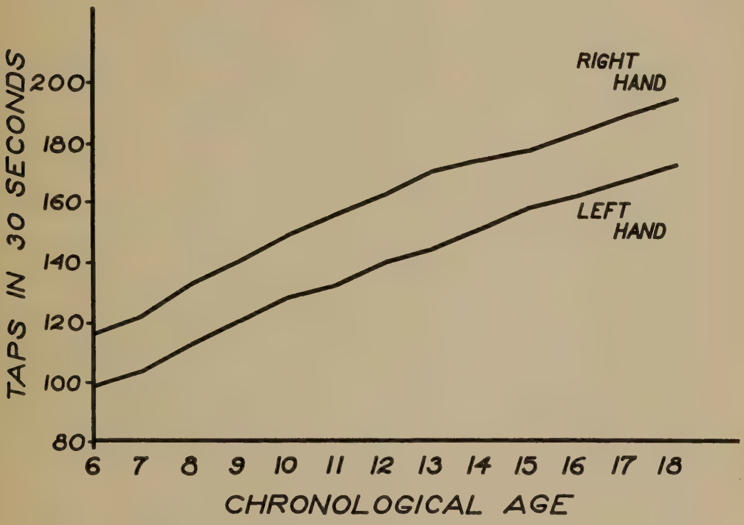

Fig. 118

Figure 119 represents the average results of a number of individuals at different ages for the time required for the completion of a relatively simple performance test. Here the curve decreases steadily with less time required for the older groups than the younger until finally the curve hits a dead level. This indicates that little more improvement may be expected after the age of approximately 13½ years. Indeed it will be seen that there is little improvement after 11 years.

The second curve (fig. 120) contains similar results for a more difficult performance test. This is indicated by the very much greater time required for successful completion of the task at all ages. In this second, and more difficult test, the degree of improvement is much more marked than it was in the easier one. Not only is the drop of the curve much steeper but marked improvement is still evident up to a greater age. It is only at 13 years that improvement ceases. From then on no improvement is evident inasmuch as the curve maintains a dead level.

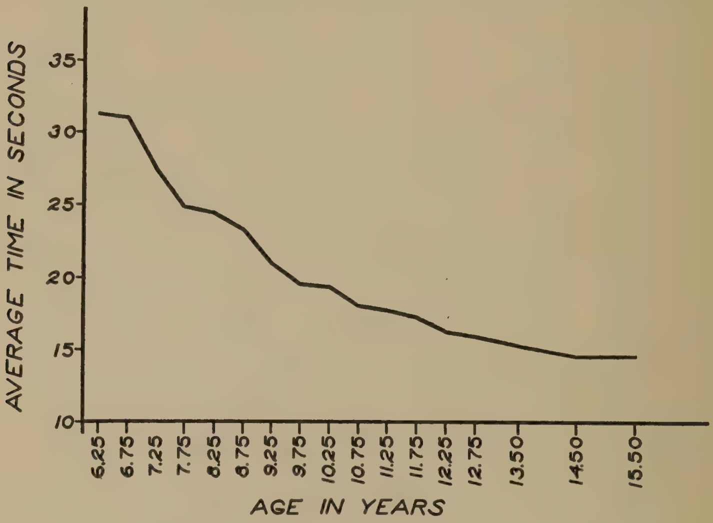

FIG. 119

It will be remembered that intelligence has been defined as the ability to solve a new problem and it has been stated that these performance tests are perhaps the best instruments yet available for the measurement of the complex of psychological characteristics which comprise intelligence. One may say from these and many other results of a similar nature that there is a very rapid growth of intelligence during the early years of the life of a normal individual, but that, as time goes on, this increase becomes less and less rapid until it comes to a gradual stop between the ages of 14–18 years for most individuals. What is true of intelligence is found also to be true of many other human abilities. The growth is rapid at first, then there is a decreasing increment of improvement until finally the adult level is reached sometime before the age of 20 years.

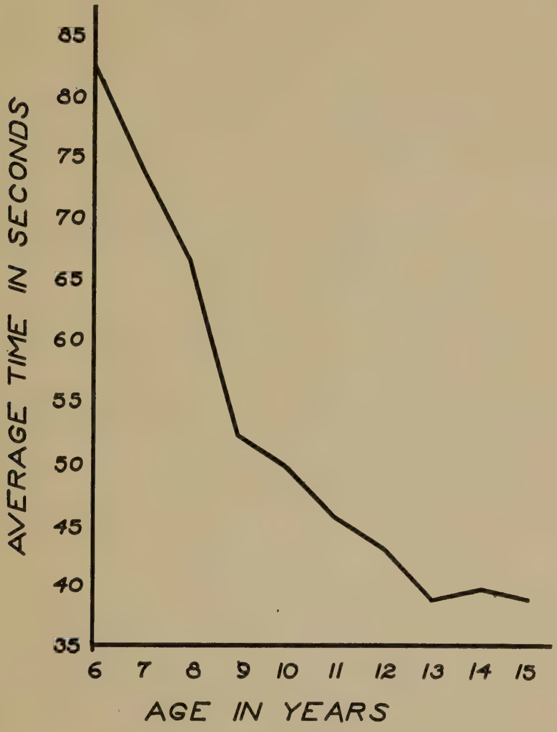

FIG. 120

It has been found that these adult levels are usually maintained over a period of some 20 to 30 years (until the ages of 40 to 50 years) and then a deterioration is frequently noted with approaching old age or *senescence*. This decrease in ability has been noted in such simple functions as the ability to hear high tones, in speed and accuracy of movement and also in such complicated combinations of psychological processes as those represented by the scores made on "intelligence tests."

Results such as these indicate, and the point cannot be too strongly emphasized, that no individual is ever the same from one year to the next. The early years of one's life are marked with very rapid increase in all psychological characteristics, both simple and complex. The rate of improvement slows down considerably during the second decade of one's life, so that by the age of 20 one's maximum degree of improvement has been reached. By this age one may be considered to have acquired one's adult status. During the fourth and fifth decades, there is again demonstrable a decrease in the abilities which have been studied, a decrease which is slow at first and which then progresses more and more rapidly until death. The problem of individual differences is seen thus to be as much concerned with changes in a given organism from time to time as it is with inequalities between different organisms.

QUESTIONS

1. What is meant by the normal curve of distribution?
2. Define a limen.
3. In general what are the properties of the distributions which are encountered in the study of abilities?
4. What methods are available for the measurement of intelligence?
5. Distinguish between intelligence and intellect.
6. What factors must be taken into consideration in the definition of feeble-mindedness and genius?
7. What important facts about the differences in ability between the sexes are known today?
8. What important considerations must be borne in mind when interpreting experimental data derived from comparative studies of the white and colored races?
9. What conclusions may be drawn from the investigations on the change of abilities during the course of life?

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CHAPTER XXII

THE INTEGRATED PERSONALITY

Until now the various topics with which psychology is concerned have been treated more or less in isolation. The simpler conscious processes of sensation and perception have been discussed in some seven chapters in which the different modalities of special sense have been isolated, each more or less into its own compartment. In another group of chapters there have been treated the more complex conscious processes of memory and thinking. In still another section, individual chapters were assigned to the various sorts of reactive processes. Each was described as a phenomenon in its own right and the relation of consciousness to each was mentioned. In the last two chapters, we have treated first, motivation and drive and secondly, the problem of individual differences.

The apparent isolation of the processes treated in the early chapters is completely at variance with the actual situation of human mind and human reaction. Such a treatment is a mere artifact of our method of presentation. It has really been forced upon us because it is necessary for one to understand each of the simpler processes if he is to understand the more complex combinations of these simpler processes. Some hints at this complexity have appeared at different points of the text. The combination of retinal and kinesthetic experiences for vision; the organization of sensory experience and past experience for perception; the reorganization of old past experiences in a new way for thinking are examples of combinations of simpler elements in the mental field. The problem of habit and especially the discussion of hierarchy of habits furnishes an example of such an organization of simpler elements in the field of reaction. In the last chapter such a combination was expressed rather than merely hinted at in the consideration of intelligence and intellect.

And now at the end of this test, we are faced with the problem of *personality,*—certainly the most complex problem in the entire field of psychology. One individual differs from another—not only in regard to some specific ability, but also with regard to his total personality. Many attempts have been made to analyze this highly complex combination of factors which make you "you" and make me "me."

One recent attempt to analyze personality has utilized as a method a mathematical analysis of scores made by a large number of individuals on each of a number of tests. As the result of his calculations, this author concludes that there exists a *general factor* evident in the results of all of the tests, as well as a particular combination of *special abilities* necessary for each of them. For this author, then, personality consists of a general factor and a combination of special abilities. He believes that this general factor is to be thought of in terms of physical and psychic energy. By no means, however, is this to be confounded with the libido of the psychoanalytic group. Apparently the adherents to this point of view believe in general that one is born with a certain amount of this general factor and that it is important in determining personality from the very beginning of one's life. One questions whether this sort of statistical approach will ever solve the problem of personality. Perhaps the problem can be approached from another point of view with greater success.

Does what has been written before, for example, give one a basis for the analysis and description of any sort of highly complex conscious and reactive behavior on the part of the mature organism? For example, the problem of *social conformity* is certainly complex. Let us see if this problem can be adequately described in terms of the analysis of conscious and reactive behavior above. For social conformity one may indicate four cardinal virtues.

1. The first of these is *obedience*, which is defined very broadly indeed. By obedience one does not only mean conformity to law and parental authority, but and this is much more important, obedience to social customs. There is no real reason why the reader should not walk down the street in midsummer dressed in a fur coat. He would certainly not be arrested, even though he would be stared at and even though he would certainly be extremely warm and uncomfortable. But the chances are that you would not do it simply because it is not an accepted social custom. There is no real reason why one should drink soup from the side rather than from the end of the spoon except that the first is socially accepted and the second is not. And in this case, social custom adopts really the less efficient method of drinking soup, as any one will tell you who has tried to feed an infant. Certainly one "acquires" soup rather better from the end of a spoon than from the side.

These social customs, as well as specific laws, are man-made. In America and in France one drives to the right of the road while in England one drives to the left. Neither is preferable to the other so long as everyone conforms to a particular custom. Some years ago, as one drove on to a Channel boat to cross from England to France, the motorist was confronted with a sign which read "Motorists are warned that in France you must drive on the *wrong* side of the road." It was only the wrong side to the Englishman; it was the right side most certainly for the Frenchman or the American.

The basis of obedience to such aspects of social conformity involves nothing more or less than the building up of certain positive habits of reaction. We have already discovered that habits start as consciously directed volitional behavior. As the result of repetition, the degree of directive consciousness drops off until the reaction takes place immediately upon the perception of the stimulus object without consciousness intervening between stimulation and reaction.

2. *Honesty* may be considered the second cardinal virtue for social conformity. Honesty may be defined broadly as respect for the person and property of other individuals. Honesty is again a product of man-made conditions. If one lived entirely alone and completely isolated from other individuals and their property, honesty would not be a problem. In such a situation the individual could take anything from his environment which he desired. It is only when man lives in groups that he must respect the person and property of other individuals. For example, much of the conflict between the Indians and the early white settlers in America hinged upon different definitions of honesty for the two groups. The Indian had no concept of private property in food or land, while the white man had definite concepts for both. Hence when the white man gave a trifling sum in beads and knives to the Indian, for what is now Manhattan Island, he believed that he owned this land as a result of the transaction, and the Indian was trespassing when he came on to it. The Indian was merely selling the right of the white man to live on this same land alongside the Indian himself.

What is the psychological basis for honesty? The basis is in an *instinctive reaction in the wrong direction.* so far as social conformity is concerned. The instinctive reaction of any child is to reach for and take any perceived object which attracts his attention and interests him. Social conformity in regard to honesty thus involves the inhibition of a perfectly normal instinctive reaction. The child or the adult must be taught either to substitute another reaction or to totally inhibit this perfectly normal instinctive reaction. It is a reaction which is highly useful for the preservation of the individual, like all other instincts, but one which must be controlled if one is to live in a group. Indeed one of the most difficult things a young child has to learn is the distinction between those objects which are his and those which are not his.

3. *Truthfulness* may be considered the third cardinal virtue

for social conformity. It may be broadly defined as some statement which is untrue and which *will injure some other individual.* An example of truthfulness is when one signs his name to a check as evidence that there is money in the bank to cover the amount. Modern business is based primarily upon credit and hence, in accordance with our definitions it is based very much more upon truthfulness than upon the proverbial honesty.

There is evidence, although not so obvious as in the case of honesty, that truthfulness has its basis in an instinctive reaction again in the wrong direction so far as social conformity is concerned. One of the most difficult things to obtain from a child is an exact statement of any event whatsoever. Children are imaginative and it is this imaginative trait which makes the totally accurate statement a very infrequent occurrence. Of course such constructive imagination is something to be encouraged in the child because it is the basis of all progress, invention and art. The distinction which the child has to learn, and it is a very difficult distinction indeed, is between the imaginative statement which will not injure some other individual (in which case it is not only right but should be encouraged) and the statement which will injure someone else (in which case only is it untruthful).

4. *Sex* is the fourth cardinal virtue for social conformity. The words sex instinct follow one another both in popular thinking and in the discussion of instinct above. Sexual reactions certainly have an instinctive basis in the wrong direction so far as social conformity is concerned. Again the normal reaction is highly purposive for the preservation of the species, but it must be inhibited or controlled in the interests of social conformity. And the inhibition of this particular instinctive reaction, in our modern society, is usually accomplished by training long before the sex glands have actually matured. All the training which one obtains in the development of modesty, almost from birth, is largely the basis for the control

and inhibition of this instinctive reaction once the sex glands are physiologically mature and able to function.

Thus this highly complex problem of social conformity resolves itself into the development of four cardinal virtues. There is one positive virtue, obedience, which involves the building up of positive habits of reaction. The other three, honesty, truthfulness and sex, are all negative virtues and each involves the breaking down or inhibition of a perfectly normal and useful instinctive reaction which may, however, clash with the demands of society. Conformity consists, in each of these cases, of the inhibition of the reaction or the substitution of some other reaction for the normal instinct. And it has been indicated above, in previous chapters, that the modification of an instinctive reaction can only be accomplished if it passes through a stage of consciously directed volition. Social conformity, then, in each of its phases, requires a volitional stage in which conscious direction of the reaction plays an all-important part.

On the basis of this discussion it is simple to explain those individuals who fail to conform socially. The *feebleminded* fail to conform because they do not possess a high enough degree of intelligence so that they may hold a single idea clearly enough in consciousness for it to exhibit its directive aspect either for building up the necessary positive habits or for breaking down those instinctive reactions which dispose them to unconformed behavior. The *insane,* of the flighty type, are unable to hold any idea in consciousness long enough for it to have directive effect in modifying behavior. The other type of insane person is unable to displace his fixed idea for a long enough time to substitute others which might lead to behavior modification. The *genius,* who fails to conform socially, is an individual with other interests and motivation so strong that other possible directive ideas are unable to displace them.

The *criminal* may be of two types. In the first, his instinctive reactions in one direction or another seem to be so strong that no amount of training seems able to effect modification. This is the habitual criminal. His failure to conform usually has to do either with honesty or with sex. For example, he is an individual who may be so unstable emotionally that he cannot control an easily aroused anger which may eventuate in his killing the other individual who acted as stimulus object. The second type of criminal is one who has never had the proper training either in building up the positive reactions of obedience or in breaking down the instinctive reactions which are at variance with honesty, sex or truthfulness.

In this discussion of social conformity, there has been mentioned practically every one of the topics outlined in previous chapters. There have been mentioned perceptions, thinking (which involves memories and intention), clearness, instinct, volition, habit and emotion. In this one finds the cue for the description of personality. What you are depends upon the combination of all of these aspects of your psychological composition and of many other things besides. Your physical body, its shape, size, and possible defects, play a part in making you what you are. Your physiological condition and reactions and your health add their share. Your glandular reactions, their amount and the ease with which such reactions may be set going by stimulation also add their share to the total picture. Thus there is a large contribution to personality which is purely anatomical and physiological and which is not usually thought of as being on the psychological level at all.

From the psychological side there are contributions of two sorts. The first has to do with capacities for experience and reaction such as thresholds for eliciting reflex, instinctive and emotional reactions, the sensitiveness of end organs for perception, and the fundamental degree of modifiability as indicated by such experience as memory span or range of attention. Most psychologists believe that these capacities for experience are *innate*, at least to the extent that the limits are set up at birth beyond which no capacity may develop. Some psychologists would go even further and declare that these capacities are not only innate but that they are *inherited* as well.

The other aspect of the psychological contributions to personality has to do with what happens to these innate capacities during the lifetime of the individual. This involves the whole background of experience and the modification of the various capacities by this experience. It has to do with memory images, each based upon some particular past experience, also with the associations which are formed between these images; the organization and reorganization of these images; one's interests, drives, intentions and motivation; the modification of instincts, the conditioning of emotions; the particular habits which have been built up and what not besides. Thus one's stock of particular motor skills may be as important a determinant of personality as one's emotional reactions, one's interests or one's motivation. All of this second group of contributing psychological factors to personality is acquired and is the result of the *environment* acting upon one's innate capacities.

Many pages have been filled with discussions of the relative importance of the effects of *heredity* and *environment* upon the development of the total personality. Much of this contains the report of experimental material such as that obtained from the study of identical twins reared apart—a study of two individuals with the same hereditary background but each subjected to a different environment. From one point of view, it is just as sensible to argue the relative importance of heredity and environment for the development of personality as it would be to argue which is the more important for human life, the heart or the lungs. Both heart and lungs are essential for the maintenance of human life. Both heredity and environment are essential for the development of human personality. It is heredity which determines what one's personality might be; it sets the limits of development, while environment determines how and what one will develop within these limits.

Thus we can close with a picture of a highly complex concept of personality made up of both hereditary, or at least innate, capacities plus the modifications of these capacities due to individual past experience by its environment. And such a concept further implies that one's personality is continually changing because fresh experiences are leaving fresh modifications resulting in new ideas, new associations, new motivation and new habits. What you are at this moment has depended upon what you were at the start and what has happened to you during your lifetime. And your neighbor is different from you simply because he was different at the start and because his environmental experiences have been different as well. All these factors, with the individual differences in both innate capacity and experience mentioned in this text, combine to make you what you are and to make you different from every other individual in the universe.

QUESTIONS

1. What psychological problems are involved in the problem of social conformity?
2. What are the chief factors involved in the making of a personality?
3. To what extent are heredity and environment factors important in the development of personality?
4. How are feeblemindedness, insanity, criminality and genius related to social conformity?

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